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ON THE RELATIONSHIP BETWEEN LINGUISTIC AND MUSICAL PROCESSING. THE CASE OF SCALAR IMPLICATURES.

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On the relationship between linguistic and musical processing. The case of scalar implicatures – Elena Menegazzo
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Abstract

The interference between language and music has become a matter of study since the formulation of Patel's hypothesis (2003), that is the *Shared Syntactic Integration Resource Hypothesis* (SSIRH). According to this framework, the processing of the syntax of both language and music requires the same neural resources, located in the frontal areas of the brain, whereas the representations associated to musical syntax are distinct from those associated to linguistic syntax, and involve distinct neural resources. In the last decades, both behavioral and neuroimaging works tested whether there is actually an interaction between language and music. From a purely syntactic perspective, some authors (Fedorenko *et al.* 2009, Slevc *et al.* 2009, Fiveash and Pammer, 2014, Hoch *et al.* 2011, Koelsch *et al.* 2005, Steinbeis and Koelsch, 2008a) confirmed SSIRH's predictions, while there is no general agreement on the results of the investigation of linguistic *semantic* processing interacting with simultaneously presented harmonic incongruities (see Besson *et al.* 1998, Bonnel *et al.* 2001, Poulin-Charronat *et al.* 2005). Until now, as far as we know, the relationship between pragmatic knowledge in language and musical grammar has not been tested, yet. In this thesis, I take up the following questions: Does implicit musical processing interfere with the computation of scalar implicatures? Is there any difference between musicians and non-musicians regarding the music/pragmatics potential interference? In providing an answer to my research questions, I will also test the Relevance Theory predictions on the computation of scalar implicatures (implicatures are expected to be cognitively costly) by evaluating and assessing previous studies in the field of experimental pragmatics.

Study 1 is a statement evaluation task whose accuracy results show a worse performance of both groups (musicians and non-musicians) while processing scalar implicatures in the presence of music. Particularly, in RTs analysis, I found that non-musicians are slower compared to musicians when computing infelicitous sentences. My study generally confirms that pragmatically infelicitous sentences are more difficult to be computed than pragmatically felicitous sentences, according to the predictions made by Relevance Theory. As for the interaction between language and music a significant interaction of music in the infelicitous context has been found. However, I deepen the analysis by adding more musical conditions in the following

study. **Study 2**, a sentence picture verification task, implements Study 1 because it tests the music/pragmatics interaction with respect to more musical conditions (no music condition, music in tune condition, out-of-key chord condition and loudness manipulation condition). Relevance Theory's predictions, according to which pragmatically infelicitous sentences are more difficult to process than pragmatically felicitous sentences, are further confirmed. Moreover, though an interference between language and music has clearly emerged, the interference emerging in my study manifested itself independently of the nature of the relevant musical condition, and more specifically, independently of whether the interfering music was in tune or with a dissonant target chord, differently from what emerged from a variety of studies testing the interference with strictly syntactic processing. In these studies, manipulating the musical condition, i.e. making musical processing more difficult by means of a dissonant target chord, has the effect of subtracting resources to syntactic processing of linguistic stimuli. Thus, it is possible to claim that as far as scalar implicature computations are involved, language interferes with music only at a general cognitive level (i.e. at the level of the general cognitive burden presupposed by some complex dual task) and not because musical syntax and scalar implicature processing consume the very same neural resources in the brain. As for the differences between musicians and non-musicians, in Study 2 no differences have been found concerning the performance of the two groups with respect to the different musical conditions. Interestingly, however, non-musicians had a worse performance than musicians while processing the infelicitous sentences.

Overall, the results show that the computation of scalar implicatures is more difficult in the pragmatically infelicitous context than in the pragmatically felicitous context, as predicted by the Relevance Theory approach. Moreover, music interferes with *pragmatic* processing of linguistic stimuli. This happens only at a general cognitive level, in accordance with the relative complexity of a dual task involving both linguistic and musical stimuli, while the data do not support the hypothesis that the musical and the pragmatic computation revolve around the same network of neural resources in the brain. This can be straightforwardly interpreted as an important class of evidence for the SSIRH. Regarding the differences between musicians and non-musicians, I found that non-musicians have a worse performance both in terms of RT (Study 1) and of accuracy (Study 2), in the pragmatically infelicitous condition, with respect to musicians. This can be due to an experimental artefact, but it might also be related to the cognitive benefits of musical training on the execution of the complex set of computations required by processing infelicitous sentences containing scalar terms.

L'interferenza tra linguaggio e musica è diventata oggetto di studio a partire dalla formulazione dell'ipotesi di Patel (2003), la *Shared Syntactic Integration Resource Hypothesis* (SSIRH). Secondo questo quadro teorico, il *processing* della sintassi linguistica e musicale richiede le stesse risorse neurali, localizzate nelle aree frontali del cervello, mentre le rappresentazioni associate alla sintassi musicale sono distinte da quelle associate alla sintassi linguistica, e coinvolgono risorse neurali differenti. Nelle ultime decadi, studi comportamentali e di neuroimmagine hanno testato l'esistenza effettiva di un'interazione tra musica e linguaggio. Da una prospettiva puramente sintattica, alcuni autori (Fedorenko *et al.* 2009, Slevc *et al.* 2009, Fiveash and Pammer, 2014, Hoch *et al.* 2011, Koelsch *et al.* 2005, Steinbeis and Koelsch, 2008a) hanno confermato le predizioni della SSIRH, mentre non c'è lo stesso accordo sui risultati di interazione nell'elaborazione della semantica presentata simultaneamente alle incongruità armoniche (vedi Besson *et al.* 1998, Bonnel *et al.* 2001, Poulin-Charronat *et al.* 2005). Fino ad ora, per quanto ne sappiamo, la relazione tra la pragmatica linguistica e la grammatica musicale non è ancora stata testata. In questa tesi, mi occupo delle seguenti questioni: il *processing* musicale implicito interferisce con la computazione delle implicature scalari? Ci sono differenze tra musicisti e non-musicisti nella potenziale interferenza tra musica e pragmatica? Nel volgermi queste domande, testerò anche le predizioni della Relevance Theory sulla computazione delle implicature scalari (ci si aspetta che le implicature siano cognitivamente più costose) analizzando studi precedenti condotti nel campo della pragmatica sperimentale.

Lo **Studio 1** è uno *statement evaluation task* i cui risultati mostrano una prestazione peggiore per entrambi i gruppi (musicisti e non musicisti) nel *processing* delle implicature scalari in presenza di musica. In particolare, dall'analisi dei tempi di reazione, ho trovato che i non musicisti sono più lenti se comparati con i musicisti nella computazione delle frasi infelici. Il mio studio, seguendo le predizioni della Relevance Theory, conferma che le frasi pragmaticamente infelici sono più difficili da computare delle frasi pragmaticamente felici. Per quanto riguarda l'interazione tra linguaggio e musica, ho riscontrato un'interazione significativa della musica nel contesto infelice. Tuttavia, ho approfondito l'analisi aggiungendo altre condizioni musicali nello studio successivo. Lo **Studio 2**, un *sentence picture verification task*, implementa lo Studio 1 poiché testa l'interazione tra musica e pragmatica con l'aggiunta di più condizioni musicali (condizione senza musica, condizione con musica in tonalità, condizione con accordo fuori tonalità e condizione di manipolazione del volume). Le predizioni della Relevance Theory, secondo cui le frasi pragmaticamente infelici sono più difficili da computare delle frasi pragmaticamente felici, sono state nuovamente confermate. Inoltre, nonostante sia emersa chiaramente un'interferenza tra linguaggio e musica, l'interferenza che emerge nel mio studio si manifesta indipendentemente dalla natura della condizione musicale, e più specificamente, indipendentemente dalla natura della frase musicale, se in tonalità o con accordo target stonato. Ciò è diverso da quanto emerso da molti altri studi che testano l'interferenza con riferimento al solo aspetto sintattico. In questi studi, manipolare la condizione musicale, ossia rendere più difficile il *processing* musicale per mezzo dell'accordo target non in tonalità, ha l'effetto di sottrarre risorse cognitive al *processing* dello stimolo linguistico sintattico. Perciò, è possibile affermare che per quanto concerne le implicature scalari, il linguaggio interferisce con la musica solo a un livello generale (vale a dire a livello del carico generale cognitivo presupposto dal doppio *task*) e non perché la sintassi musicale e il *processing* delle implicature scalari richiedano le stesse risorse neurali nel cervello. Per quanto riguarda le differenze tra musicisti e non musicisti, nello Studio 2 non si riscontrano differenze se si guardano ai risultati dell'interazione nelle diverse condizioni musicali. È comunque interessante notare che i non musicisti hanno una prestazione peggiore dei musicisti nel *processing* delle frasi infelici.

Nel complesso, i risultati mostrano che la computazione delle implicature scalari è più difficile nel contesto pragmaticamente infelice rispetto al contesto pragmaticamente felice, così come predetto dalla Relevance Theory. Inoltre, la musica interferisce con il *processing* linguistico pragmatico ma solo ad un livello cognitivo generale. Ciò avviene in accordo con la relativa complessità del doppio *task* che comprende sia stimoli linguistici sia stimoli musicali, mentre non ci sono dati in supporto dell'ipotesi che la computazione musicale e pragmatica ruotino attorno agli stessi circuiti neurali nel cervello. Ciò si può considerare come una chiara evidenza per la SSIRH. In riferimento alle differenze tra musicisti e non musicisti, ho trovato che i non musicisti hanno una performance peggiore rispetto ai musicisti sia in termini di tempi di reazione (Studio 1) sia di accuratezza (Studio 2), nella condizione pragmaticamente infelice. Questo può esser dovuto ad un artefatto sperimentale, ma potrebbe anche esser collegato ai benefici cognitivi del training musicale nell'esecuzione del set complesso di computazioni richieste nel *processing* delle frasi infelici che contengono il termine scalare.

1. Introduction

The relationship between language and music has been studied from many different perspectives. The first link between these two human capacities was made by Leonard Bernstein in 1973, when he delivered the Charles Eliot Norton Lectures at Harvard University. Bernstein supported the idea that, like language, also music has its own "musical grammar". As a result of the lectures can be seen the first theory formulated in terms of rules of musical grammar, that is the Generative Theory of Tonal Music proposed by Jackendoff and Lerdahl in 1983. Since then, a growing interest has surrounded the relationship between these disciplines, spreading the domain of research, from pedagogical and theoretical purposes, to the supposed common origin of language and music, to neuroscience.

So, we can ask: what's the actual interest of studying the relationship between language and music? According to some theorists (e.g. Mithen, 2008; Brown *et al.*, 1999) music and language are linked since the origins of the human species. This is probably due to the universality and uniqueness of language and music in our species, as they reflect the changes in the human brain that have taken place (Carroll, 2003). Another point of interest in exploring the relationship between language and music is a theoretical one. After Leonard Bernstein's lectures, some scholars took inspiration from the Chomsky's Generative Grammar (1957) and Langacker's Cognitive Grammar (1991) and they hypothesized that there are analogies between the construction of the linguistic and the musical sentence (e.g. the GTTM by Jackendoff and Lerdahl, 1983, the Identity thesis for Language and Music by Katz and Pesetsky, 2011). Language and music have also been studied in their relationship from a neuroscientific perspective. Of particular interest are the studies of the brain regions involved while processing both (e.g. pitch, syntax), the common cognitive processes underlying both and around the question whether music can shape the cerebral anatomy of the human brain. Specifically, exploring what are the differences and the similarities can deepen the understanding of the mechanisms that underlie our communicative abilities. In fact, this relationship has been explored also for a pedagogical and therapeutic purpose. Music can help to acquire and to recover non-musical abilities (e.g. Yoo, 2009; Wilson *et al.*, 2009), and understanding how music and language are related has implications for how language disorders can be treated, as in the case of rehabilitation programs, like the Melodic Intonation Therapy (MIT) described in Zumbansen, Peretz and Hébert (2014), that is one of the most formalized treatments used for patients with Broca's aphasia.

Although all these approaches are worth analyzing, this thesis focuses on the relationship between language and music in the neurobiological framework, and, in particular, based on Patel's specific hypothesis, known as the *Shared Syntactic Integration Resource Hypothesis*.

1.1 Dissertation outline

From a neuroscientific perspective, language and music as cognitive capacities are based on a multiple dimension of cognitive processes and of knowledge manipulation. This led to a transdisciplinary work that cuts across different disciplines, such as linguistics, the study of musical harmony, psychology and cognitive neuroscience.

The present thesis is organised as follows. Chapter 2 explores the relationship between language and music in the neurobiological framework. I start by introducing some of the neuropsychological works (section 2.2) that led to the evidence for domain-specificity. On the one hand, in fact, there are well known cases of aphasia (a language disorder on the comprehension of formulation of language) without amusia (a neurodevelopmental disorder mainly characterized by a defect in pitch processing), on the other hand there are cases of people with amusia but without any linguistic disruption. In contrast to this evidence, I am going to explore the literature about neuroimaging studies (section 2.3) that probe the relationship of language and music using different techniques, like fMRI, EEG, MEG and PET. These works uniformly suggest that since recently the relationship between language and music has not been appropriately investigated because neuropsychological data, as observed above, convincingly supported the claim that language and music are domain-specific. On the contrary, works based on neuroimaging techniques question the domain-specificity assumption. In section 2.4 I will present the *Shared Syntactic Integration Resource Hypothesis* (SSIRH), a theoretical framework proposed by Patel in 2003 that tries to reconcile neuropsychological with neuroimaging data and, in the following section (2.5), I will present some works that tested the predictions of the SSIRH. Concluding the review of this debate, in section 2.6 I present more recent studies on neuropsychology that converge to Patel's hypothesis. Last section (2.7) discusses the literature on the differences between musicians and non-musicians.

Chapter 3 is dedicated to experimental pragmatics. After a brief introduction into the topic (3.1), in sections 3.1.1 and 3.1.2 I present the experimental works on the computation of Scalar Implicatures in both children and adults that tested the theoretical predictions.

In chapter 4 I will present the experimental protocols that tested the computation of scalar implicatures in adult musicians and non-musicians, in an experimental setting in which they were listening to a musical background vs. a setting with no music (Experiment 1), as well as in a setting involving loudness manipulation vs. out-of-key target chord (Experiment 2). The aim of these experiments was to test language-related processing in the pragmatic context giving rise to scalar implicatures (while at the same time evaluating the consequences for the SSIRH). Following the presentation of both experiments, I present the results and the discussion for each.

As a conclusion, in chapter 5 I will discuss all the data I gathered, as well as their implications. In a nutshell, my results provide substantial evidence for the Relevance Theory regarding the computation of Scalar Implicatures, as proved by the higher error rate for pragmatically infelicitous sentences than for pragmatically felicitous sentences. Moreover, in both experiments I found a significant interaction between language and music limited to the most difficult linguistic condition indicating that the presence of music in the background affects the way in which a sentence, requiring the computation of an implicature, and thus involving higher computational resources, is processed.

As importantly, concerning the SSIRH, I can claim that pragmatic computation interferes with music but not with musical grammar. More specifically, whereas I already have important evidence to the effect that linguistic syntax interferes with music processing, as predicted by the SSIRH, my data show that these interference effects do not extend to pragmatics in the same way. Finally, I did not find any difference between musicians and non-musicians in the interaction between language and music. However, non-musicians had a worse performance in the computation of scalar implicatures in general. I will discuss whether this is an artefact of my experimental protocol or whether it can provide further indications on the interaction between language and music.

2. Language and music. Literature review

2.1 Introduction

In this chapter, I am going to review the literature about the interaction between language and music in a cognitive framework.

Neuropsychological studies have often been taken as evidence for domain-specificity, because many authors reported cognitive deficits that are selective for language but not for music (e.g. aphasia) or for music but not for language (e.g. amusia). What shifted the ground in the works between the language-music relation were the neuroimaging results. In these works, I witness an interesting challenge to domain-specificity, because similarities in language and music processing in the elicitation of the P600 and other ERP components have been found, and, through fMRI and PET methods, there emerged an overlap of brain regions involved in processing linguistic and musical structure, including (but not limited to) Broca's area.

In 2003, Patel proposed a theoretical framework aimed to reconcile the contradictory evidence on the interaction between language and music by focusing on syntactic processing. This theoretical framework was called the *Shared Syntactic Integration Resource Hypothesis* (Patel, 2003, 2008). Basically, Patel observed that though there are aspects of language and music that are different in their structural organization, these two cognitive capacities show, in terms of cognitive processing, a number of deep connections.

After the presentation of Patel's proposal, I will discuss some of the works that tested the interaction between language and music in the theoretical framework of the *Shared Syntactic Integration Resource Hypothesis* with neural and behavioural methods. To conclude this chapter, I report recent evidence in neuropsychology that provide further support to Patel's proposal.

2.2 Evidence for domain-specificity in language and music. Neuropsychological studies.

Aphasia is a language disorder caused by damage to one or more of the language areas of the brain and it can be due to a stroke, head injury, cerebral tumour, or degenerative dementias such as Alzheimer's disease (Damasio, 1992). Patients who suffer from this sort of brain lesion experience a disturbance of the comprehension and production of language. It occurs not only in languages based on auditory signals but also in those based on visual-motor signs (sign languages). It may compromise the written code of any type of language, as it compromises multiple aspects of language, such as syntax, the lexicon and word composition. It is worth noting that aphasia is a "disorder of linguistic processing, a disruption of the mechanisms for translating thought to language. Aphasia is not a disorder of perception" as in the case of deaf people (Damasio, 1992: 531). There are two broad categories of aphasia: fluent and non-fluent, and there are several subtypes of these groups. However, what is relevant for our discussion here is the dissociation reported for linguistic and musical processing in people who suffers from aphasia.

Since more than a century it is well known that in patients who experience aphasia, musical and singing abilities are preserved (Jackson, 1871). However, there are also many cases of disturbance of musical function concurrent with aphasic disorders (Benton, 1977; Brust, 1980; Geschwind *et al.* 1968). Marin (1982) reported 12 cases of aphasia without amusia, 19 cases of amusia without aphasia, 33 cases of amusia and aphasia, and 9 cases of verbal and music alexia. Studying amusia, Brust (1980) has noted that the several types of amusia are not predicted by the presence or absence of aphasia.

In 1985, Basso and Capitani reported the case of patient NS, which is of particular interest because, contrary to many other cases of aphasia with spared musical function where patients were less severely impaired in language, NS had a persistent global aphasia and ideomotor apraxia with spared musical function. NS was an orchestral conductor with a degree in violin. At the age of 67, in a concert tour in the US, he developed slight right hemiparesis, right homonymous hemianopia and global aphasia. His diagnosis was an infarct in the territory of the middle cerebral artery. Since then, NS was tested several times both on linguistic abilities (oral and written) and on musical abilities (written, oral, while playing and while conducting), and he also underwent language rehabilitation. Considering his linguistic abilities, speech was confined to some formulaic expressions, picture naming was nil, spontaneous writing and writing to dictation were severely affected. Repetition and reading aloud were impossible; moreover, there was severe apraxia. When he was tested on his musical capacity, it was observed that whenever a request required language production or comprehension, NS failed, while he reproduced musical rhythm fairly well, even if not naming the notes. Moreover, he was still able to play the piano with both hands, though the right hand was slightly paretic. While language rehabilitation never produced significant improvement, musical execution always improved with practice. On a test of music incongruity detection, NS never failed. He was also observed while conducting. NS was perfectly able to point out mistakes in execution and when he conducted some orchestral performances, such as Verdi's *Nabucco* and Casella's *Serenata per archi*, which are very difficult (because of the size of the orchestra and the number of singers in Verdi and because of the continuous changes of time and measures values in Casella), he was applauded by the critics' judgments. In conclusion, NS was functionally performant when conducting; he also could play the piano, but as Basso and Capitano (1985: 411) pointed out "even more striking was the dissociation between NS' verbal and musical performances".

A strong dissociation between music and language has also been observed by Polk and Kertesz (1993). They reported the case of patient CW, a 58-year-old male guitar teacher. At the age 56 he presented a generalized decrease in cognitive function. CT and MRI scans showed enlarged ventricles and diffuse cerebral atrophy with greater left involvement. He was diagnosed with a progressive aphasia or possible Alzheimer's disease. During the following years he repeated neuropsychological tests that reported significant decline in all cognitive functions. Polk and Kertesz (1993: 110) tested him on linguistic and musical abilities and they found "non-fluent, unintelligible and scanty verbal output" that "contrasts directly with ratings of his music performance".

Another case of a professional musician and composer who presented a progressive aphasia with a severe anomia has been reported by Tzortis *et al.* (2000). MM was severely impaired in naming of non-musical stimuli, but he normally named musical instruments' sounds. Another often cited case is the one of the composer

Vissarion Shebalin (1902-1963) reported by Luria *et al.* (1965). Shebalin suffered two strokes in his left hemisphere, affecting the temporal and parietal regions. His language disorder manifested itself after the second stroke, but, in those years, he was a fruitful composer and composed in fact also a symphony that was commented by Shostakovich as a "brilliant creative work" (Luria *et al.*, 1965: 292). Other cases of aphasia without musical disruption are reported by Assal (1973) in a professional pianist and conductor, by Assal and Buttet (1983) in a piano professor and organist, Judd *et al.* (1983) in a composer, conductor and professor of music, Signoret *et al.* (1987) in a composer and regular organist. However, research on neural plasticity has revealed significant differences between the brains of professional musicians and those of non-musicians in a variety of ways, among them, the increased gray matter density in specific regions of the frontal cortex and increased corpus callosum size (Patel, 2008; Schlaug *et al.*, 1995; Gaser and Schlaug, 2003). As pointed out by Patel (2008), given the substantial differences between professional musicians and non-musicians and given that professional musicians are not representative of the ordinary population, we should avoid inferring domain-specificity based on the dissociations found for cases of aphasia without amusia. Peretz *et al.* (2004) have argued that such cases exist, but in a closer examination, the cases she reported are of "pure word deafness", something sometimes referred to as a form of aphasia, but in fact a form of auditory agnosia. Pure word deafness is qualitatively different from pure aphasia, because an individual with pure word deafness can no longer understand spoken material but can produce language in other modalities, such as writing. In contrast, in the case of pure aphasia language is damaged across modalities (Caplan, 1992). What should be noticed here, is that, according to Patel (2008), all these cases of aphasia without amusia are not convincing because they consider only professional musicians and there are no reported cases of ordinary individuals with brain damage. Moreover, as reported above, there are also cases of the coexistence of aphasia with amusia as in the cases reported by Souques and Baruk (1926) in a piano professor, Alajouanine (1948), who reported on the case of the composer Maurice Ravel, Jellinek (1956) reporting the situation of a professional singer who accompanied himself while playing guitar, Wertheim and Botez (1961) in a professional violinist, Brust (1980) reporting the case of a music student and also the case of a professional jazz double-bassist, Mavlov (1980) in the case of a professional violin player and professor of music, Hofman *et al.* (1993) in the case of an amateur violinist, among many others.

Another claim for the domain-specificity for the two domains is given by the cases of amusia without any linguistic disorder. Amusia is a neurodevelopmental disorder mainly characterized by a defect in pitch processing. It can be acquired, occurring as a result of brain damage, or congenital, thus, a lifelong disorder of music processing present since birth. It occurs despite normal hearing and other cognitive functions as well as normal exposure to music. Amusia can be present both in comorbidity with aphasia or without any other disorder. Cases of pure amusia, as cases of pure aphasia, have been considered significant because they imply that brain networks are specialized for specific functions (Ayotte *et al.* 2002; Justus, Bharucha, 2002; Nune-Silva, Geraldi Haase, 2013; Peretz, 1992; Peretz, Belleville, 1997; Peretz, Coltheart, 2003; Peretz, Zatorre, 2003; Piccirilli *et al.* 2000). For example, Peretz (1993) and Peretz *et al.* (1994) reported the case of GL, a patient who presented auditory atonalia as a consequence of brain damage due to an aneurysm on the right middle cerebral artery. A year later, in a control evaluation, a mirror aneurysm on the left side was also found. GL's capacity for music was preserved for the discrimination between single pitches and he was also sensitive to differences in melodic contour in short melodies. However, he lacked sensitivity to musical key. In an experiment on tonal closure, GL and control participants were asked to listen to a musical context followed by a probe tone that scans all the chromatic pitches. Participants had to judge on a Likert's scale of five points the goodness of the probe tone in the completion of the context. Diatonic tones should be preferred over non-diatonic tones, and triad tones should be preferred over non-triad. Among the triad chords, the tonic, being the highly referential note in a musical key, should receive the highest rating. Expectancies were confirmed by control participants. In contrast, GL judged on the basis of his preserved melodic contour between the penultimate and final tone. Thus, he "failed to exploit tonal cues but relied on nontonal ones for judging the adequacy of melodic endings" (Peretz, 1993: 47). In a test on Tonal Preference, GL refuses to perform the task, therefore the authors tested GL in a Discrimination Task, in a "same-different" classification, where half of the trials contained pairs of tonal melodies, and half pairs of nontonal melodies. GL's performance was far below that of controls, failing again to show evidence of using the tonal scale as a way to organise and retain melodic information. It is important to notice that while tests on music revealed some deficits, GL scored in the normal range on standardized aphasia tests. Thus, he is a case of "amusia without aphasia".

In order to classify amusia as a learning disability that affects music abilities, Ayotte, Peretz and Hyde (2002) studied the behavioural manifestations of congenital amusia. Their results show that congenital amusia is related to failure in processing pitch variations and the deficit extends to impairments in music memory and recognition, in singing and in the ability to tap in time to music. As noted in the case of GL, it seems that amusia is a highly specific musical deficit. Amusics retain the ability to process and recognize speech, including speech prosody, and they also recognize environmental sounds (such as animal cries and ringing sounds) and human voices not differently from controls.

2.3 Challenges to domain-specificity. Neuroimaging studies

Based on the conspicuous data coming from neuropsychology we should conclude that music is a modular system that is not related to language. What challenges this view are the neuroimaging studies involving different types of techniques, such as EEG (electroencephalography), MEG (magnetoencephalography) and fMRI (functional magnetic resonance imaging).

The first work that compared and found similarities in linguistic and musical processing in normal individuals is the one of Patel, Gibson, Ratner, Besson, Holcomb (1998a). In the first experiment, the authors manipulated the linguistic structural context before a fixed target phrase, in order to have a different difficulty when integrating the latter with the prior context. The ERP (event-related potential) waveform was found to have a larger positivity (a P600 effect) when the sentence was ungrammatical than in the grammatically complex sentence type, which was in turn more positive than the grammatically simple sentence type. Thus, if sentences were grammatically complex or ungrammatical, target phrases had a positive-going ERP component, while if sentences had a simple syntactic context before the context, the P600 effect was not observed. The P600, or "syntactic positive shift" brain potential (Osterhout, Holcomb, 1992, 1993; Hagoort, Brown, Groothusen, 1993) is a positive-going component of the ERP that is elicited by words that are structurally difficult to integrate into meaningful sentences. Basically, we can say that the P600 component is related to syntactic difficulties in processing. Patel *et al.* (1998a), in a second experiment, manipulated the target chord in a musical phrase, thus manipulating musical grammar. The target chord was either within the tonality of the musical phrase or it was an out-of-key chord, that could be from a nearby key or a distant key. It is important to notice that it was deviant only in the harmonic sense, given the structural norms of Western European tonal music. Participants had to judge musical phrases as acceptable in all three conditions. Results show that "musical sequences with out-of-key target chords elicited a positive ERP component with a maximum around 600 msec post-target onset" (Patel *et al.* 1998a: 10). The authors also noted that the waveform was different for the three types of target chords. After testing syntactic incongruity in language and in music, the authors statistically compared the amplitude and the scalp distribution, and they found that the P600 latency range was indistinguishable for the two cognitive systems. On this basis, they suggested that the P600 reflects processes of structural integration which are shared by language and music.

Further evidence for the overlap of music and language processing has been provided by Maess, Koelsch, Gunter and Friederici (2001). The aim of their work was to establish where the neural substrate of syntactic musical processing is localized. Electrically, a syntactically incongruous chord elicits an early right-anterior negativity (ERAN). Using MEG, the authors found that the mERAN (the magnetic equivalent of ERAN) was generated "in each hemisphere within the inferior part of BA44 (inferior part of the pars opercularis) in the left hemisphere", known as Broca's area (Maess *et al.* 2001: 542). Their results indicate that Broca's area and its right-hemisphere homologue might be involved in the processing of musical syntax, and this suggests that these regions of the brain are less domain-specific than what previously believed (cf. Koelsch, Siebel, 2005). Later research using fMRI and PET (positron emission tomography) converged with the electrophysiological measures. Koelsch *et al.* (2002) tested ten non-musicians in an fMRI study. Stimuli were chord-sequences containing unexpected musical events. Participants were asked to detect clusters and deviant instruments. In the fMRI analysis it was found that the processing of musical sequences required the activation of a cortical network that comprised numerous brain structures. Several of these structures are known to be involved in the processing of music, such as the right, the posterior and the anterior STG, BA 44, left BA 44/6, that are respectively related to the processing of pitch, pitch perception, the processing of tonal and melodic processing as well as melodic representations, working memory for pitch and for the processing of sequential sounds (Liegeois-Chauvel *et al.*, 1998; Peretz *et al.*, 1994; Platel *et al.*, 1997; Samson and Zatorre, 1988; Zatorre, 1985; Zatorre *et al.* 1994; Zatorre and Samson, 1991). However, it is important to notice that all these structures are also well known to be involved in language processing with both auditory (Zatorre *et al.,* 1992; Mummery *et al.,* 1999; Meyer *et al.,* 2000; Pöppel, 1996; Friederici *et al.,* 2000; Binder *et al.,* 1994; Schlosser *et al.*, 1998; Bellin *et al.*, 2000; Friederici, 1998) and visual stimuli (Just *et al.*, 1996; Shaywitz *et al.*, 1995; Mazoyer *et al.*, 1993). This is particularly the case of Broca's and Wernicke's areas as demonstrated by lesion- and imaging studies. In this respect, Koelsch *et al.* (2002) claim that these findings do not support the strict dichotomy between auditory language and music processing, but rather suggest considerable overlap. Moreover, they confirm that music, like language, has a syntactic dimension.

Using positron emission tomography (PET), Brown *et al.* (2006) tested amateur musicians while improvising melodic or linguistic phrases in response to unfamiliar, auditorily presented melodies or phrases. Results show that core areas for generating musical phrases are in left BA 45, right BA 44, bilateral temporal planum polare, lateral BA 6, and pre-SMA. Core areas for generating sentences appeared to be in bilateral posterior superior and middle temporal cortex (BA 22, 21), left BA 39, bilateral superior frontal (BA 8, 9), left inferior frontal (BA 44, 45), anterior cingulated, and pre-SMA. Directly comparing the areas activated by the two tasks, the authors claim that the activated areas are nearly identical, including the primary motor cortex, supplementary motor area, Broca's area, anterior insula, primary and secondary auditory cortices, temporal pole, basal ganglia, ventral thalamus, and posterior cerebellum. Even if Brown *et al.* (2006) found that differences between melodic and sentential generation were in lateralization tendencies, with language favouring the left hemisphere, "many of the activations for each modality were bilateral, and so there was a significant overlap" (Brown *et al.* 2006: 2791).

Levitin, Menon (2003, 2005), in a fMRI study, investigated the neuroanatomical correlates of musical structure. Participants were asked to listen to classical music and scrambled versions of that same musical pieces and the authors compared the brain responses to that stimuli. Scrambled music was used to break temporal coherence; however, it was balanced for low-level factors, that are psychoacoustic features such as pitch, loudness and timbre. Given that there was no differential activation in auditory cortex between the two conditions, experimenters confirmed that they were well matched for low-level acoustical features. Levitin and Menon (2003, 2005) found that classical music activated Broadmann Area 47, a region that has been associated with the processing of linguistic structure in spoken and sign language, and its right hemisphere homologue. As a result, Levitin and Menon (2003: 2149) believe that "Broadmann Area 47 and the adjoining anterior insula constitute a modality-independent brain area that organizes structural units in the perceptual stream to create larger, meaningful representations. That is, it may be part of a neural network for perceptual organization". Considering all these data, and data from other works such as Vuust *et al* (2006, 2011b) on the involvement of BA 47 in the processing of temporal coherence that subserves both language and music, and Sammler *et al.* (2011: 659) who claim that " the left IFG, known to be crucial for syntax processing in language, plays also a functional role in the processing of musical syntax", it is possible to say that according to neuroimaging studies, there is an overlap in brain areas while processing syntax in language and music. I would like to emphasize that the overlap occurs only with respect to syntax. In the discussion, Sammler *et al.* (2011: 659) state that their results "are consistent with the notion that Broca's area supports the processing of syntax in a rather domain-general way". The idea that it is syntax at the core of the overlap is widely agreed. Among the studies already reported, also Fadiga *et al.* (2009), in a review, focused on the inferior frontal gyrus and the ventral premotor cortex because of the claims regarding these areas as not only related to language production. Based on the data gathered in his work, Fadiga *et al.* (2009: 448) state that "language, action, and music share a common syntactic-like structure".

2.4 Reconciling the paradox: The "*Shared Syntactic Integration Resource Hypothesis*"

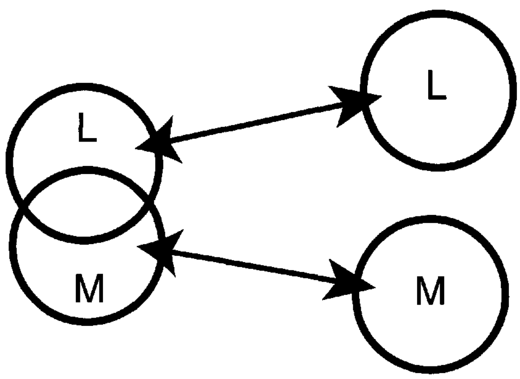
As reported in the previous sections, neuropsychological data yield rather different perspectives from neuroimaging data on the relation between language and music in the brain. In order to disentangle this paradox, Patel (2003, 2008) proposed the *Shared Syntactic Integration Resource Hypothesis* (SSIRH). His starting point is the proposal of a conceptual distinction between syntactic representation and syntactic processing, that is on the one hand the distinction between long-term structural knowledge in a domain (in this case, the associative networks that store knowledge for words in language and for chords in music), and on the other hand operations conducted on that sort of specific knowledge for the purpose of building coherent percepts. A basic principle is that language and music involve domain-specific representations. For example, knowledge of words and their syntactic properties involve a different set of representations than the one of chords and their harmonic relations. The SSIRH posits that the syntactic representations stored in long-term memory are different for language and for music. This explains why, according to Patel (2003, 2008, 2012), these representations can be selectively damaged leading to the neuropsychological evidence discussed above. The second part of the SSIRH is the idea that when similar cognitive operations are engaged on these domain-specific representations, the brain shares neural resources between the two domains. Thus, it is the case that these operations share neural resources and this explains neuroimaging data. As reported by Patel (2008), such "dual system" approaches have already been proposed by researches who studied the neurolinguistics of syntax. For example, Caplan and Waters (1999) proposed that the working memory system for linguistic syntactic operations is supported by frontal areas of the brain, and Ullman (2001) considers that a symbol-manipulation system for linguistic syntax reside in frontal areas. Patel's approach (2003, 2008) is actually a dual system approach, but he does not consider that music and language share a specific memory system or symbol manipulation system. Instead, he proposes that what is shared by musical and linguistic syntactic processing emerges from a comparison of cognitive theories of syntactic processing in both language and music. The reason why Patel (2003, 2008) chose these theories is because of their strong empirical basis and because they converge remarkably.

For the processing of language, Patel (2003, 2008) reported the *Dependency Locality Theory* (DLT) and the *Expectancy Theory* (ET). The DLT has been developed by Gibson (1998, 2000) aiming to account for the perceived complexity differences of grammatical sentences and for what guides preferences in the interpretation of syntactically ambiguous sentences. According to the DLT, when comprehending linguistic sentences, two distinct components are involved and both of them consume neural resources. The first component is the structural storage, which keeps track of the perceived syntactic categories (e.g. after a noun a verb is predicted). The second component is the structural integration which connects one word to another in the sentence structural context. The basic idea of this theory is that locality influences the cost of integration. More the element and the site of integration are distant, and more the cost increases. In the DLT, distance has to deal with a linear measurement rather than a hierarchical one. That is, it is measured by computing new "discourse referents" since the site of integration, rather than by counting nodes in the syntactic tree. Reading time experiments confirm the predictions of the DLT, because longer reaction time reflects the cost of processing. As pointed out by Patel (2008), the main idea here is that when distant elements have to be mentally connected, they require more cognitive resources.

The ET is a different theoretical perspective for the processing of language which suggests that a preceding perceived word creates a syntactic expectation. Each expectation reflects concurrent structural analysis of the sentence. In the case a word does not match the expectations, resources must be reallocated in order to change the preferred structural interpretation. Psycholinguistic studies have confirmed this idea and what is noteworthy in our discussion is that ET integrates the DLT approach.

In the case of music processing, Patel (2003, 2008) reports the *Tonal Pitch Space Theory* (TPST) presented by Lerdahl (2001). Empirical findings (cf. Patel 2008) show that music has perceived relations between scale tones, chords and keys. These relations have a psychological distance, and TPST actually provides a method for deriving tree structures which effectively show the distances between harmonic relations. The basic idea here is that harmonic tension increases with tonal distance between chords. The TPST has been supported by empirical evidence, as in Lerdahl & Krumhansl's (2007) work. The authors suggest that music is actually perceived in a hierarchical sequential manner. What is relevant here is that chord relations are perceived in terms of distances in a cognitive space that is structured for pitch classes, chords and keys.

The main point of the linguistic and musical syntactic theories is the notion that structural integration is a key part of syntactic processing. Moreover, all the theories predict resource consuming for the structural interpretation of a (musical or linguistic) sentence. Given the distance and the expectancy cost in resource processing, Patel (2003: 678) proposes that "overlap in the syntactic processing of language and music can thus be conceived of as overlap in the neural areas and operations which provide the resources for syntactic integration". This is what Patel calls the *Shared Syntactic Integration Resource Hypothesis*. According to the SSIRH, there is a dedicated area of the brain that provides the resources for syntactic integration. This area rapidly selects low-activation items from the "storage" area, that is the "representation networks" and it activates the selected items in order to integrate the linguistic and musical stimuli. Even if there is not yet a firm answer regarding the neural location of this brain area, Patel (2003, 2008, 2012), capitalizing on current research on language processing, hypothesised that it is located "in frontal brain regions that do not themselves contain syntactic representations but that provide resources for computations in posterior regions where syntactic representations reside" (Patel, 2008: 283).



1. Schematic diagram (from Patel, 2008: 283) of the functional relationship between linguistic and musical processing. L, language; M, music. In this diagram it is possible to see on the right the stored representations for language and music, that are separated in distinct brain areas, whereas on the left it is represented the neural overlap of the networks which provides neural resources for integrating the stored representations. Arrows indicate functional

connections between networks. Patel (2008: 283) wants to note that "the circles do not necessarily imply highly focal brain areas. For example, linguistic and musical representation networks could extend across a number of brain regions or exist as functionally segregated networks within the same brain regions".

Patel (2003, 2008, 2012) notes that in order to test the neural localization hypothesis, tests with localization techniques such as fMRI, based on within-subjects analysis while subjects are processing linguistic and musical syntax, still have to be done.

The strong point to be made about the SSIRH is that it can reconcile neuropsychological evidence and neuroimaging data. For example, the ERP component P600, elicited for both language and music processing in Patel *et al.* (1998a), "reflects syntactic integration processes that take place in posterior/temporal brain regions" (Patel, 2008: 284). A further confirmation comes from localization studies, such as Koelsch *et al.* (2002), because these studies find that frontal language areas are activated in musical harmonic processing. As for neuropsychological evidence, regarding acquired amusia Patel (2008) claims that it is due to a damage to brain areas specifically involved in processing musical syntax rather than in syntactic integration processes. This idea is confirmed by cases involving damaged superior temporal gyri (Peretz, 1993; Peretz *et al.* 1994; Patel, Peretz, *et al.*, 1998b; Ayotte *et al.*, 2000), which are related to long-term representation of harmonic knowledge. Concerning congenital amusia, Patel (2008) claims that it consists in a developmental failure to process musical pitch. As reported by Peretz and Hyde (2003) and Foxton *et al.* (2004), subjects who suffer from congenital amusia have basic psychophysical deficits in pitch discrimination, besides deficits in judging the direction of pitch changes. As observed by Patel (2008), this problem is associated with a failure in cognitively representing musical scale, chord, and key structure. Thus, amusics cannot process musical syntactic structure. So, the traditional observation according to which amusia (also called "tone deafness") can exist without any linguistic disorder, is derived in Patel (2008: 284) by proposing that, since amusics are not able to process musical syntactic structure, amusia "is largely irrelevant to the study of music-language syntactic relations".

As pointed out in the previous section on neuropsychological studies, cases of patients with aphasia without amusia reported in the literature were of professional musicians with a high musical expertise. Patel (2008) does not consider these cases as correctly describing the larger population. Furthermore, most of the reported cases are out of date, thus Patel (2008) suggests that more work should be done here before reaching firm conclusions.

In presenting the SSIRH, Patel (2003, 2008) formulated some predictions that could guide future research on the relationship between linguistic and musical syntactic processing. The first prediction concerns the simultaneous syntactic integration in music and language. In this case, given that linguistic and musical syntactic integration rely on common neural resources, and because resources are limited (Gibson, 2000), the result should be an interference between the two. This prediction can be tested through interference paradigms, in which musical and linguistic sentences are presented together and the focus is on how musical processing interferes with language processing. The second prediction of the SSIRH is about aphasia. According to Kolk, Friederici (1985), Haarmann, Kolk (1991), Swaab, Brown, Hagoort (1998) and Kaan, Swaab (2002), deficits of Broca's aphasics in syntactic comprehension processing can be due not to a damage in the syntactic representations, but to a disruption of the processes that activate and integrate linguistic representations in posterior language areas. In this case, the SSIRH predicts that comprehension deficits in linguistic syntax are related to harmonic processing deficits in music.

2.5 Testing the predictions of the *Shared Syntactic Integration Resource Hypothesis* with neural and behavioural methods.

Previous works on the relationship between language and music found dissociations between the two or reported an interaction supposedly to be due to non-specific factors. The reason why these works could not provide support for the SSIRH was related to the type of stimuli. Regarding music, stimuli were of harmonic manipulations, but, as for linguistic stimuli, only linguistic *semantic* processing was tested.

In 1998, Besson *et al.* tested 16 professional musicians on incongruity detection in language and in music. Participants were asked to carefully listen 200 opera excerpts (sung by a professional musician and without instrumental accompaniment) and to stay focus on both language and music in order to detect semantic and harmonic incongruities. The authors found that linguistic semantic incongruities elicited the N400, the ERP component with a negative-going deflection with its peak at around 400 msec post-stimulus onset, "typically considered an ERP index of semantic processing or contextual integration because its amplitude is modulated by its relation and fit to the ongoing context, be it a single word, a sentence, or a multisentence discourse" (Hillyard, Kutas, 2002: 435). In contrast, out-of-key notes gave rise to P300 components. Thus, Besson *et al.* (1998: 497) claim that "harmonic processing is not affected by the semantics of the sentence" and this result supports the idea that "semantic and harmonic violations are processed independently".

In a behavioural work, Bonnel *et al.* (2001) using the same material of Besson *et al.* (1998), asked participants to carefully listen the sung sentences. Participants were asked to detect either the semantic or the melodic incongruity (single task) or to judge the incongruity of both (dual task). The authors found that the dual task was not more difficult than the single task, thus confirming the results of Besson *et al.* (1998). Hence, these works supported the idea that language processing is independent from musical processing.

In contrast, Poulin-Charronat *et al.* (2005) found an interaction between musical syntactic processing and linguistic semantic processing. Their material was composed of eight-chord sung sentences, with the last word being either semantically related, as in "La giraffe a un très grand *cou*" (The giraffe has a very long *neck*), or unrelated to the previous linguistic context, as in "La giraffe a un très grand *pied*" (The giraffe has a very long *foot*). Another half of the sentences were identical, with the exception that target words were non-words. The harmonic function of the target word was manipulated, being either the most hierarchically relevant tonic chord, or the less stable subdominant chord. Participants were asked to listen each sequence and to decide quickly and accurately whether the last word was real or a non-sense. The authors were interested in reaction times to real words and they found that the RT difference between semantically expected and semantically unexpected word was diminished when the final chord functioned as a subdominant chord. Moreover, testing both musicians and non-musicians, they found that the two groups behaved very similarly, indicating that this process is independent of an explicit musical knowledge. Thus, Poulin-Charronat *et al.* (2005) showed that linguistic *semantic* processing can interact with syntactic processing in music. However, when discussing the data, the authors claim that the interaction is probably due to a general attentional mechanism rather than by shared processing resources in language and music. Patel (2008) considers that this work is of particular interest because it can direct future works to investigating the indirect effects of music on language based on general attentional mechanisms, such as loudness manipulation or timbre manipulation.

After Patel's (2003) proposal, many scholars started studying the relationship between linguistic and musical processing with respect to syntax in the framework of the SSIRH. A neuroscientific work is the one of Koelsch, Gunter, Wittfoth and Sammler (2005), who investigated through EEG the simultaneous processing of linguistic written sentences and auditorily presented chord sequences. In Experiment 1 musical sequences were presented that ended with the expected tonic chord, or with the unexpected Neapolitan chord. Linguistic material comprised syntactically correct sentences with a high cloze probability such as "Er trinkt das kühle Bier" (He drinks the (neuter) cool (neuter) beer (neuter)), syntactically correct sentences with low cloze probability such as "Er sieht das kühle Bier" (He sees the (neuter) cool (neuter) beer (neuter)) and syntactically incorrect sentences with a high cloze probability, such as "Er trinkt den kühlen Bier" (He drinks the (masc) cool (masc) beer (neuter)). Music material was auditorily presented while words were visually presented. Each word appeared synchronously with each chord. Participants were asked to focus only on the linguistic sentence and they had to judge whether the last sentence was correct or incorrect. The left anterior negativity (LAN) is an ERP component that is associated to linguistic stimuli that violate syntactic structure, while the early right anterior negativity (ERAN) is associated to violation of music-syntactic information (Friederici, 2002; Koelsch, Friederici, 2003). Koelsch *et al.* (2005) found that when sentences were completely grammatical, but they were accompanied by a syntactically out-of-key chord, the predicted ERAN was produced. Vice versa, when music was as expected, without deviant chord, but the linguistic sentence ended ungrammatically, a normal LAN was produced. In the case where participants had to listen to simultaneous syntactic incongruities in language and in music, results show that the brain responses were not simply additive, but that there was actually an interaction. The LAN, which was elicited by syntactically incorrect words, was clearly reduced when incorrect words were presented simultaneously to syntactically irregular musical chords. In contrast, the semantic aspect of language, investigated by high/low semantic probability, and indexed by the N400, was not affected by the processing of music-syntactic violations (indexed by the ERAN). In order to be sure that it is not a deviance-related negativity that has an effect on linguistic syntax processing, the authors carried out a second ERP experiment which was identical to Experiment 1, except that single tones were presented instead of chords, and the last tone was either a standard one, or a physically deviant tone, which usually elicits a mismatch negativity (MMN) (Schröger, 1998; Näätänen, 1992). Results from Experiment 2 confirm that there is actually an interaction in processing linguistic and musical syntax. In the second experiment, in fact, the LAN was not affected when words were presented on physically deviant tones. Koelsch *et al.* (2005: 1574) claim that "it is possible that the neural resources for syntactic processing were at least partly consumed by the (quite automatic) processing of the music-syntactic irregularities, resulting in a decrease of resources involved in the generation of the LAN. This finding is surprising, given that the attentional focus of participants was directed on the linguistic information". These results have also been confirmed by a work of Steinbeis and Koelsch (2008a: 1169) who found that "the ERAN was reduced only when presented concurrently with a syntactic language violation and not with a semantic language violation".

Behavioural works that are noteworthy in testing the SSIRH, are Fedorenko *et al.* (2009), Slevc *et al.* (2009), Hoch *et al.* (2011) and Fiveash and Pammer (2014).

The work of Fedorenko *et al.* (2009) investigated how syntax in language and in music is simultaneously processed by using sung materials. Linguistic complexity was manipulated via the distance between dependent words, specifically, they used subject-extracted relative clauses, such as "The boy that helped the girl got an "A" on the test", and object-extracted relative clauses, such as "The boy that the girl helped got an "A" on the test". Instead, musical complexity was manipulated by the presence of an out-of-key note vs. an in-key note on the last word of the relative clause, that is "girl" on the subject-relative clause reported above, or "helped" in the object-relative clause. In order to test whether it is actually the structural integration that it is difficult and not a general attentional mechanism as proposed by Poulin-Charronat *et al.* (2005), Fedorenko *et al.* (2009) added a loudness manipulation condition, that is a 10 dB increase in volume on the target word. After each sentence, participants were asked a comprehension question, and accuracy was assumed to reflect processing difficulty. The authors observed that comprehension accuracy was lower in the object-extracted relative clauses vs. the subject-extracted relative clauses, but crucially, in the presence of the out-of-key note this difference was larger. This shows an interactive pattern between linguistic and musical syntactic processing. In contrast, the auditory-anomaly condition did not produce this effect, which proves that it is actually the syntax of language that interacts with music. Moreover, the interaction is not due to a perceptual salience effect in the musical conditions. It is in fact interesting to note that the accuracies in the auditory-anomaly condition are quite similar to the in-key conditions. These results are consistent with the SSIRH, because they prove that some aspect of structural integration in language and music relies on shared processing resources.

Further support for the SSIRH has been provided also by Slevc *et al.* (2009) by manipulating syntactic processing demands presented simultaneously in language and music. Additionally, the expectation related to linguistic semantic processing was tested to determine whether the interaction is actually specific to syntax. The test was a self-paced reading task on garden-path sentences, and it included either a full or a reduced sentence complement, such as "After the trial, the attorney advised (that) the defendant <u>was</u> likely to commit more crimes". In the conditions where "that" is omitted, a garden path sentence is created with localized processing difficulty on "was", due to a syntactic expectancy violation. In the semantic manipulation, words were added with either high or low cloze probability, such as "The boss warned the mailman to watch for angry <u>(dogs / pigs)</u> when delivering the mail", thereby making the semantic interpretation expected or unexpected at the critical word. As for the music material, Slevc *et al.* (2009) presented, simultaneously to linguistic sentences, musical sequences in Bach-style chord progression. They created two versions of the same musical excerpt. One version with all chords respecting the C major tonality, and another identical version except for one chord concomitant to the target word, which was replaced with a chord from a distant key, that is an out-of-key chord. Because out-of-key chords are harmonically unexpected, the authors crossed syntactic and semantic expectancy in language with harmonic expectancy in music. Results were drawn from reading times for the critical word. Slevc *et al.* (2009) found a three-way interaction between the type of linguistic manipulation (syntactic or semantic), linguistic and musical expectancy. They found that when participants encountered an unexpected word, be either syntactically or semantically unexpected, they read them more slowly than the expected counterparts. In the case sentences were read while processing a harmonically unexpected chord concomitant to the critical word, an interference was found. Interestingly, the interference was found only when the out-of-key chord was presented simultaneously to the syntactic unexpected word and not when presented together with the semantic unexpected word. In a second experiment, Slevc *et al.* (2009) added a further condition manipulating the timbre of the critical chord, which either had the expected piano timbre, or a pipe-organ timbre. It was found that manipulations of musical timbre did not interact with syntactic or semantic expectancy in language. Once again, these results confirm that linguistic and musical syntactic processing share neural resources.

In 2011, Hoch, Poulin-Charronat and Tillmann tested again the SSIRH by using a cross-modal paradigm on syntactic and semantic linguistic processing overlapping with listening musical sequences. The authors asked participants to read sentences and to perform a lexical decision task on the last word, which was syntactically expected or unexpected (Experiment 1) or semantically expected or unexpected (Experiment 2). Simultaneously to the presentation of written sentences, participants listened to musical sequences that ended on either the expected tonic chord (I), the most hierarchically relevant chord of the musical scale, or the less-expected subdominant chord (IV). Linguistic manipulation in Experiment 1 consisted of a morphosyntactic violation through gender disagreement, such as "Le méchant chien dort dans la(fem.) *niche* (fem.)" (The nasty dog is sleeping in the(fem.) *kennel*(fem.)) vs. "Le méchant chien dort dans le(masc.) *niche*(fem.)" (The nasty dog is sleeping in the(masc.) *kennel*(fem.)). In Experiment 2, semantically expected sentences were the syntactically expected sentences used in Experiment 1, while sentences with the semantically unexpected word were for example "Le méchant chien dort dans la *tente*" (The nasty dog is sleeping in the *tent*). Results from Experiment 1 showed that expected words were processed faster and more accurately than syntactically unexpected words. It reflects the influence of morphosyntactic expectancies. This effect was modulated by the tonal function of the simultaneously presented musical chord. When the target word was presented together with the less-expected subdominant chord the effect was reduced compared to an expected tonic chord. As regard to music interaction, there was an effect of musical expectancy only for the expected words, but not for the syntactically unexpected words. The expected words showed a tonic facilitation, in contrast, syntactically unexpected words did not show the same facilitation. Hoch *et al.* (2011: 4) suggest that "musical structure and linguistic syntax processing tap into the same processing resources, thus hindering the otherwise observed tonic benefit". Compared to the results of Slevc *et al.* (2009) and Fedorenko *et al.* (2009), Experiment 1 reports a different type of interactive pattern between the processing of syntax in music and language. In Slevc *et al.* (2009) the effect of the syntactic garden-path sentences compared to the simple sentences was greater when they were presented with an unexpected out-of-key chord than with an expected in-key chord. According to Hoch *et al.* (2011) the different interactive patterns with music-syntactic processing might be due to the type of linguistic-syntactic manipulation. However, overall findings suggest an interactive influence between simultaneous music-syntactic and linguistic-syntactic processing further supporting the SSIRH. In Experiment 2, with semantically expected vs. unexpected words, it was confirmed that expected words are processed faster and more accurately than unexpected words (see McNamara, 2005 for a review); moreover, a main effect of tonal function was found with faster and more accurate results for words concomitant to the expected tonic chord than those concomitant to the less-expected subdominant chord. What is relevant here is that "the semantic priming effect did not modulate the musical expectancy effect nor was it modulated by the musical expectancy effect" (Hoch *et al.* 2011: 6). It is thus the case that music-syntactic processing and linguistic-semantic processing do not share cognitive resources. All in all, Hoch *et al.* (2011) provide more evidence to support the SSIRH.

The final study described here, by Fiveash and Pammer (2014), combines the SSIRH and the syntactic working memory (SWM) theory by Kljajevic (2010). The SWM proposes the presence of a short-term memory mechanism specialized for syntax, where syntactic information reside while the rest of the musical or linguistic sentence is processed via working memory. By hypothesis, this is where the overlap in resource networks occurs in the processing of linguistic and musical syntax (Kljajevic, 2010). The existence of a working memory system that is specific to syntax processing was early supported by Caplan and Waters (1999), who suggest that there is a subset of verbal working memory that specifically deals with syntactic information used in sentence interpretation. With respect to the working memory model proposed by Baddeley and Hitch (1974), and later extended by Baddeley (2000), Kljajevic's proposal is that SWM is separate but related to the working memory model. Baddeley and Hitch (1974) and Baddeley (2000)'s working memory model include both a phonological loop, which is thought to consist of two parts: a phonological store and an articulatory rehearsal process, and a visuospatial sketchpad, besides a central executive and an episodic buffer. Even if Baddeley (2000) further integrated the working memory model, he does not specifically mention how syntax is processed, and this is where Kljavevic locates his SWM theory.

Turning to Fiveash and Pammer's (2014) experiment, the authors wanted to investigate whether musical syntax and linguistic-syntax draw on SWM by looking at the interaction of music with a syntactic violation paired with both word lists and complex sentences. Fiveash and Pammer (2014) determined their prediction basing themselves on the SSIRH. Language stimuli were word lists of five monosyllabic items, such as "sand, bat, light, pear, mole", complex sentences were object-extracted relative clauses vs. subject-extracted relative clauses from Fedorenko's work (2009). Music material comprehended an in-key/control condition, a musical syntactic manipulation with an out-of-key chord and a control condition with instrument manipulation (with a flute instead of an acoustic guitar). Participants were presented with either a word list or a sentence on the screen while music simultaneously started. They were then asked to verbally recall as much as they could about the word list or the sentence. Aiming to study the SWM, the authors assumed that word lists would go only with the phonological loop, while complex sentences were assumed to make use of both the phonological loop and of access to SWM. Consistently with the SSIRH, "the results support the hypothesis with memory for complex sentences decreasing significantly when paired with the music syntactic condition compared to the music normal condition. The same pattern was not found in word lists, showing that the syntactic music manipulation had different effects on word lists and sentences" (Fiveash, Pammer, 2014: 200-201). Also in this case, the instrument manipulation control condition, inserted to exclude a possible explanation in terms of a general attentional mechanism, was not significantly different from the in-key music condition, whereas it was if compared with the out-of-key musical condition.

Taken together, the results of the studies reviewed above point to shared neural resources between music and linguistic syntactic processing, thus confirming the predictions of the SSIRH.

2.6 Reconciling neuroimaging and neuropsychological data.

As reported in section 2.4, the cases of congenital and acquired amusia are not relevant in the study of the relationship between language and music. Briefly summing up, the reason for that is that for acquired amusia the brain damage is located in brain areas that are specific to syntactic processing in music rather than syntactic integration processes, while congenital amusia is considered a developmental failure to process musical pitch. Congenital amusics, in fact, fail in cognitively representing musical scale, chord, and key structure. Thus, it is the case that amusics are not able to process musical syntactic structure.

Cases of aphasia without amusia reported in section 2.2 should be carefully considered because these cases are of professional musicians and not of ordinary people and they are mainly out of date. Indeed, new evidence from aphasia in non-musicians points to an association between linguistic and musical syntactic disorders. Patel, Iversen, Wassenaar, and Hagoort (2008) examined linguistic and musical syntactic processing and linguistic semantic processing in individuals with Broca's aphasia and agrammatic comprehension. Patients with Broca's aphasia have a marked difficulty with sentence production, though speech comprehension is quite often spared. However, when they were carefully tested, a linguistic syntactic comprehension deficit clearly emerged. Patel *et al.* (2008) tested in two different experiments Broca's aphasics on their sensitivity to grammatical and semantic relations in sentences, and on their sensitivity to musical syntactic relations in chord sequences. In Experiment 1 they used an explicit task, that is, an acceptability judgment of novel sequences, whereas in Experiment 2 the task was implicit and investigated musical syntactic processing through harmonic paradigm. A language pre-test was administered to both groups of Broca's aphasics (those of experiments 1 and 2). It was a "sentence-picture matching task" with sentences varying across five levels of syntactic complexity, from active semantically irreversible sentences, to an intermediate level of complexity was the passive structure, where the most complex linguistic complexity was represented by sentences with an embedded subject relative clause in the passive voice. Correct matching was possible only on the basis of syntactic information. Participants had to determine who did what to whom in these sentences. Broca's aphasics, compared to controls, performed significantly worse on this test. This result confirms that they did indeed have a syntactic comprehension deficit in language. Participants were also administered a music pre-test to check for possible basic pitch perception or memory problems. Except from two aphasic and one control participants that performed at chance level and thus were excluded, the remaining participants did not significantly differ on basic pitch discrimination or memory skills. To test the interaction of music and language, Patel *et al.* (2008) asked participants to perform acceptability judgments on musical and linguistic sequences. Linguistic material was composed of sentences with a syntactic error, such as "De matrozen roepen de kapitein en *eist* een lekkere fles rum" (The sailors call for the captain and *demands* a fine bottle of rum) thus with a syntactic agreement error, and of sentences with a semantic error, such as "Anne kraste haar naam met haar *tomaat* in de houten deur"(Anne scratched her name with her *tomato* on the wooden door), where the word "tomaat" (tomato) is semantically anomalous. The authors tested both syntactic and semantic comprehension to determine whether musical syntactic abilities were specifically related to linguistic syntax. For the musical task, participants listened to 60 chord sequences (from Patel *et al.* 1998) and they had to judge whether the musical sequence was acceptable or not. Half of the sequences were in-key, while in the other half an out-of-key chord occurred within the phrase, thus creating a syntactic incongruity. Participants had always to firstly complete the music test and then the language test. The results show that aphasics had a significantly worse performance than controls on detecting anomalies in chord sequences. This indicates that there is actually a deficit for this group while processing musical tonality. They also showed significant deficits on the linguistic syntactic task. Looking at the correlation between performance on the music task and the language syntax task, for the aphasics, the simple correlation was not significant. Surprisingly, when the controls were included in the correlation, performance on the music syntax task became a predictor of performance on the language syntactic task. It is also noteworthy that when the same analysis was run by adding the semantic anomalous condition, performance on the music task did not predict linguistic performance.

Hence there seems to be a shared process that links music syntax to language syntax also in patients with Broca's aphasia.

In Experiment 2, Patel *et al.* (2008) probed harmonic priming in a second group of Broca's aphasics. The same linguistic pre-test of Experiment 1 was administered to the experimental group in order to establish a linguistic syntactic comprehension deficit. The authors also administered two short musical pre-tests to the participants. The first tested the ability to discriminate tuned vs. mistuned chords, while the second tested auditory short-term memory. In these tests, except from two aphasics that were then excluded from further analysis, the other Broca's aphasics performed as well as controls. The main experiment consisted of two-chord musical sequences used to test harmonic priming. In this task the first encountered chord primes the processing of the second target chord (Bharucha, Stoecking, 1986; Bharucha, 1987). The priming effect is reflected in shorter reaction times and higher accuracy when the target chord is harmonically close to the tonal centre created by the context. This advantage is not only due to psychoacoustic similarity of context and target, but to the harmonic distance in the cognitive space of chords and keys. Thus, the harmonic priming effect is an index of implicit knowledge of syntactic conventions in tonal music. Participants were asked to judge whether the target chord was tuned or mistuned according to the preceding chord. However, Patel *et al.* (2008) were interested in the RT, because faster RT to harmonically close vs. distant chords is evidence of harmonic priming. Results show a normal harmonic priming for controls, with faster RT to close vs. distant well-tuned targets. In contrast, aphasics did not show a priming effect and they were even faster on distant targets, even if not significantly. This suggests that their responses were driven by psychoacoustic similarity rather than by harmonic structure.

Experiment 1 and 2 are thus the first to prove that aphasics that have syntactic comprehension problems in language also have problems in activating the implicit knowledge of harmonic relations that Western non-musicians normally exhibit. Patel *et al.* (2008: 788) claim that results from Experiment 1 and Experiment 2 are "consistent with the SSIRH, and with the idea that these aphasic individuals have diminished processing resources for structural integration in both domains".

Further evidence from neuropsychological studies has been provided by Jentschke (2007) and Jentschke *et al.* (2005, 2008). The aim of these works was to probe the ERP components that are related to music-syntactic processing in children with language difficulties. Specifically, they studied the processing of the ERAN and of the N5 in children with specific language impairment (SLI), which is a primary linguistic disorder in the absence of non-linguistic causes. A main characteristic of SLI children is that they show severe difficulties with grammar (van der Lely, 2005). Their performance on syntactic comprehension is significantly worse than the performance of typically developing children. It seems that lexical and pragmatic skills are quite intact, phonology and argument structure abilities are slightly worse, while morphosyntactic skills, and in particular the processing of grammatical morphemes, are the most impaired (Jentschke *et al.* 2008). The authors find it interesting to study music perception in children with a linguistic disorder, especially considering that this language disorder is commonly related to syntax. EEG data were recorded while children listened to chord sequences. Musical sentences were five chords long and the final chord function was a harmonically regular tonic (I), or a slightly irregular supertonic (II). During the experiment, participants sat in front of a monitor while watching a silent movie of an aquarium. The authors found that neither ERAN nor N5 were elicited in children with SLI, whereas both were evoked in age-matched control children. This means that typically developing children from 4 to 5 years of age already possess cognitive representations of the syntactic regularities of Western tonal music; in contrast, children with SLI, even if they did not differ from typically developing children in their processing of acoustic features, did not evoke the ERAN and the N5 components. According to Jentschke *et al.* (2008: 1948) "this provides further evidence that musical and linguistic syntax are processed in shared neural systems".

Interestingly, all these recent data coming from neuroimaging, neuropsychology and behavioural works that tested the SSIRH found significant evidence for the overlap of neural resources between linguistic and musical processing at the level of syntax. As for *semantic* processing Besson *et al.* (1998), Bonnel *et al.* (2001), Koelsch *et al.* (2005), Slevc *et al.* (2009) and Hoch *et al.* (2011) did not find any interaction between linguistic *semantic* and harmonic processing. Moreover, even if Poulin-Charronat *et al.* (2005) argue for a general attentional mechanism, they found an interaction in semantic processing in language and harmonic processing in music. What is relevant in this work is that, by now, it has not yet been studied whether there exists an interaction between linguistic *pragmatic* computations and harmonic processing in music.

2.7 Musicians and non-musicians. Are they different?

The debate on whether musicians are "different" if compared to the ordinary population has been pursued both in behavioural and neuroimaging studies. One of the reasons that led to this research question is that perceptual and cognitive skills can be shaped and enhanced through our experience in the world (see for example, Goldstone, 1999; Palmeri & Gauthier, 2004), and expert musicians are an ideal population to be studied. Professional musicians are in fact dedicated to music training since very early in life and they follow rigid practice regimens totalling approximately 10.000+h of lifetime practice by early adulthood (e.g. Ericsson, Krampe & Tesch-Romer, 1993; Krampe & Ericsson, 1996). During their training, instrumentalists have to deal with clear perceptual and cognitive demands. They continuously perceive and control their instrument's acoustic signal, sustain attention to their output, reproduce complex and variable sound sequences, and also when playing in orchestras or with other instrumentalists they must carefully analyse the output of other musicians. Moreover, there are differences across the types of the instrument or musical-genre played. For instance, musicians that perform classical music, if compared to rock or jazz musicians, can better discriminate differences in frequency (Kishon-Rabin *et al.*, 2001; Vuust, Brattico, Seppänen, Näätänen, & Tervaniemi, 2012). Percussionists are more stable when reproducing temporal intervals with respect to string musicians and non-musicians (Cicchini *et al.*, 2012); string musicians match frequency differences less variably than percussionists (Hoffman, Mürbe, Kuhlisch, & Pabst, 1997); and trained vocalists can sustain pitch better than instrumentalists (Nikjeh *et al.*, 2009). Also data from EEG and MEG show differences in the timbre response of the specific musical instrument played, both in adults (Pantev, Roberts, Schulz, Engelien, & Ross, 2001; Shahin, Bosnyak, Trainor, & Roberts, 2003) and in children (Shahin, Roberts, Chau, Tranor, & Miller, 2008; Shahin, Roberts, & Trainor, 2004; Trainor, Shahin, & Roberts, 2003). Moreover, differences have been found between string and woodwind players compared to piano players. String and woodwind players, who continuously must attend to and adjust intonation during performance, can discriminate frequency differences more finely (Micheyl *et al.*, 2006; Spiegel & Watson, 1984). However, in an attempt to probe whether there are any differences between violinists and pianists in fine-grained auditory perceptual threshold associated with long-term training on specific instruments, Carey *et al.* (2015) found that basic acoustic features are manipulated differently by violinists and pianists, but they do not differ in their perceptual sensitivity to these features.

Turning back to the comparison between musicians and non-musicians, it has been widely proved that musicians tend to outperform non-musicians in perceiving fine differences in a number of basic auditory properties, which includes frequency and/or pitch (Amir, Amir, & Kishon-Rabin, 2003; Kishon, Rabin, Amir, Vexler, & Zaltz, 2001; Koelsch, Schröger, & Tervaniemi, 1999; Micheyl, Delhommeau, Perrot, & Oxenham, 2006; Nikjeh, Lister, & Frisch, 2009; Parbery-Clark, Skoe, Lam *et al.* 2009; Spiegel & Watson, 1984), tone interval size (Siegel & Siegel, 1977; Zarate, Ritson, & Poeppel, 2012, 2013), temporal interval size (Cicchini, Arrighi, Cecchetti, Giusti, & Burr, 2012; Ehrlé & Samson, 2005; Rammsayer & Altenmüller, 2006), and timbre (Pitt, 1994).

Evidence on sustained attentional abilities in musicians showed that musicians outperform non-musicians on auditory but not visually sustained attention measures (Strait *et al.*, 2010); however, Rodrigues, Loureiro, & Caramelli (2013) also showed an advantage for musicians on visual attention metrics. It is interesting to note that Conway *et al.* (2010) found that deaf children with cochlear implants are impaired in visual sequence learning, suggesting that a period of auditory deprivation may have a major impact on cognitive processes that are not specific to the auditory modality.

As for the ERP components, musicians have larger amplitude and/or shorter latencies compared to non-musicians with respect to many ERP components, such as the N1, P2, MMN, P300, reflecting enhanced cortical attentive and pre-attentive processing of linguistic (e.g. Chobert *et al.*, 2011) and musical features (e.g. Vuust *et al.*, 2011a; Pantev, *et al.*, 1998; François & Schön, 2011; Koelsch *et al.*, 1999; Shahin *et al.*, 2003; Van Zuijen *et al.*, 2005). According to Baumann *et al.* (2008) the increased auditory evoked potentials in musicians (N1-P2) reflects an enlarged neural representation for specific sound features rather than selective attention biases.

Kraus and Chandrasekaran (2010) found that at the sub-cortical level, musicians have more robust encoding of linguistic and musical features. This is shown by earlier and larger brainstem responses. Fujioka *et al.* (2004) found that, compared to non-musicians, musicians show larger MMNs to deviants in contour and in interval structure inserted in 5-notes melodies.

On auditory scene analysis, Zendel and Alain (2009, 2013) found that musicians segregate harmonic complexes better than non-musicians and more often report hearing a harmonic as a separate auditory object.

François and Schön (2011) and François *et al.* (2012) (but see also Shook *et al.*, 2013) assessed the effects of musical expertise in adults and active musical training in children on speech segmentation abilities. Adult musicians outperformed non-musicians with a larger amplitude on the N1 component. Additionally, the amplitude of a later N400-like fronto-central negative component was more sensitive to the transitional probabilities in musicians compared to non-musicians. Thus, musicians have a robust representation of musical and linguistic structures. It was also found that musicians showed both a larger P2 and MMN to low transitional probability melodies than to high transitional probability melodies while non-musicians did not show these effects. François and Schön (2011) and François *et al.* (2012) suggest that musicians learned the musical structure better than non-musicians. Longitudinal tests on children also confirm that the group of children who undertook music lessons showed a significant increase in speech segmentation abilities after one and two years of training. After two years, this behavioural benefit was proved also by greater sensitivity to the fronto-central N400-like component to transitional probabilities. Thus, it is the case that music training enhances sensitivity to statistical regularities in speech.

Other differences between musicians and non-musicians are shown by the electrophysiological indices of auditory perception (e.g. Seppänen, Pesonen, & Tervaniemi, 2012; Tervaniemi, Just, Koelsch, Widmann, & Schröger, 2005; Tervaniemi *et al.*, 2009; Marie, Magne, & Besson, 2011). Tervaniemi *et al.* (2009) compared the N2b component amplitude in musicians and non-musicians and found that musicians show an increased N2b for attended intensity, frequency and duration deviances in speech and musical sounds. Seppänen *et al.* (2012) also found significant reduction in P3b amplitudes when attending to subtle pitch deviances. Thus, there are differences in attention between musicians and non-musicians in the detection of potentially less salient acoustic cues (Fujioka, Ross, Kakigi, Pantev, & Trainor, 2006; Strait & Kraus, 2011; Strait *et al.*, 2010).

Some researchers also show that there are morphological differences between musicians and non-musicians. For instance, Bermudez and Zatorre (2005) show that musicians have a larger gray matter concentration in the auditory cortex, Sluming *et al.* (2002) an increased gray matter density and volume in the left inferior frontal gyrus, Broca's area, and other authors (Schlaug *et al.*, 1995; Chan *et al.*, 1998; Keenan *et al.*, 2001; and Luders *et al.*, 2004) also add that musicians have a larger planum temporale than non-musicians. However, it is not really surprising that sound features are better perceived by musicians. This is due to the quantity of time spent focusing on sounds and the way they are generated, paying close attention to pitch, timber, duration, and timing. These acquired skills transfer to non-musical abilities. For example, musicians, both children and adults, perform better if asked to detect fine contour modifications in the prosody of an utterance (Schön *et al.*, 2004; Magne *et al.*, 2006). At the end of an utterance, adult musicians have better performances and larger ERP components to metric incongruities (Marie *et al.*, 2011). Anvari *et al.* (2002) and Milovanov *et al.* (2008, 2009) found evidence for a possible correlation between musical and linguistic aptitudes in children; and this is true also for adults (Foxton *et al.*, 2003; Slevc, Miyake, 2006). Some authors also argued for a positive influence of musical training on linguistic skills (Butzlaff, 2000; Overy, 2003; Gaab *et al.*, 2005; Tallal and Gaab, 2006; Forgeard *et al.*, 2008; Moreno *et al.*, 2009; Parbery-Clark *et al.*, 2009).

However, it is not the case that all the literature that investigates the behaviour of musicians and non-musicians on musical and on linguistic tasks found differences. This is the case of Poulin-Charronat's *et al.* (2005) study on semantic priming in vocal music. The authors probed how musical grammar may interfere with the processing of semantically related or unrelated sentences in sung sequences. Participants, half non-musicians and half professional musicians, were asked to perform a lexical decision task, thus, the musical task was implicit. Poulin-Charronat *et al.* (2005) found that both groups behaved very similarly, thus they claim that, as in this case, not all the musical processes require an explicit knowledge of music. This is also what is found in Slevc *et al.* (2009), having both groups performing equally in the garden-path test; this is consistent with a large set of data showing that harmonic priming occurs at an implicit level and results from the implicit learning of Western tonal regularities (Tillmann, Bharucha & Bigand, 2000) as with other data showing that the auditory cortex of non-musicians can process musical relations automatically (Brattico, Näätänen, & Tervaniermi, 2002; Koelsch *et al.*, 2000; Koelsch, Schröger, & Gunter, 2002; Trainor, McDonald, & Alain, 2002). Moreover, it is noteworthy that when differences have been found in behavioural studies the task asks for explicit attention. In fact, Loui, Wessel (2007: 1091) found that when the demand for selective attention was removed, the performance of musicians and non-musicians was similarly affected by harmonic expectation. According to the authors, the differences between musicians and non-musicians that vary in relation to the explicit/implicit task "are consistent with a model of attention in which musical training selectively facilitates responses to harmonically expected chord progressions, so that musicians form automatic expectations for prototypical chord progressions and are unable to ignore these harmonic expectations". Additionally, the automatic expectation model is confirmed by electrophysiological data, as in Loui, Grent-'t-Jong, Torpey, & Woldorff's (2005) work, which shows that the violation of harmonic expectation is heavily modulated by attention in non-musicians. Thus, Loui and Wessel (2007) account for the whole set of data reported by suggesting that the formation of harmonic expectations is affected by both attention and musical training. When experimenters asked for a selective attention to the music, musicians recruited their musical skills to focus on harmony, but when they did not choose for selective attention, musicians became sensitive to harmonic expectations as non-musicians did.

3. Experimental pragmatics: the case of scalar implicatures

Pragmatics is a branch of linguistics which deals with the study of how the properties of language interact with the contextual factors in the interpretation of utterances.

In linguistics, it is possible to distinguish between sentence and utterance. While a sentence is an abstract object, with properties that are phonological, syntactic and semantic and that are assigned by the grammar of the language; an utterance is a concrete object because it has a definite location in time and space. Once an utterance is realized, also a sentence is, but not vice versa. An utterance is, in fact, a realization of a sentence that has all linguistic properties of a sentence, but it also has further properties. These added properties are linked to the situation in which sentences are realized, crucially involving the contextual parameters introduced by the presence of a speaker/hearer.

Pragmatic theories are concerned with the interaction of both linguistic and non-linguistic properties at play.

The philosopher Paul Grice (1989) defended two main ideas that are widely accepted by linguists. The first idea is the existence of a speaker's meaning and of a sentence meaning. The speaker's meaning is the communicative content that is shared by the interlocutors, while the sentence meaning is the subpart of the process that corresponds to the decoding of the sentence uttered. The recognition of the speaker's meaning is a process that is realized without any distinct awareness of the sentence meaning, that is, of the semantic properties that the grammar assigned to the sentence. In a conversation, it is presupposed that the hearer will (finally) recognize the intended meaning of the utterance as produced by the speaker. Consider, for instance, the answer in the following exchange:

(1) Bill: Do you like Mozart sonatas?
Anne: Some of them.

The answer of Anne "some of them" is interpreted as conveying Anne's intention to induce in Bill the belief that Anne likes some of Mozart sonatas, but not all of them. The speaker's meaning of the relevant proposition is thus *Anne likes some of Mozart* *sonatas, but not all of them*. The actual meaning of the sentence is thus much richer than the meaning that was literally expressed by the speaker, which is clearly related to the standard logical interpretation of *some* (Anne like some and possibly all Mozart's sonatas).

The second idea that Grice defended is the cooperative nature of conversational exchanges in communication. Grice argues that when we speak, the conversation should meet some specific standards that are related to the fact that it is a cooperative activity. Grice labels these standards as *Cooperative Principle* and he defines it by claiming that participants to a conversation, fulfilling the cooperative principle, are required to "make [their] conversational contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which [the interlocutors] are engaged" (Grice, 1975: 45). In order to give this principle a specific content, Grice (1975: 45-46) proposes four maxims that have to be respected in order for the principle to be obeyed. These are:

Maxims of Quantity
1. Make your contribution as informative as is required (for the current purpose of the exchange)
2. Do not make your contribution more informative than is required

Maxims of Quality
Supermaxim. Try to make your contribution one that is true.
1. Do not say what you believe to be false.
2. Do not say that for which you lack adequate evidence.

Maxim of Relation
Be relevant.

Maxims of Manner
Supermaxim. Be perspicuous.
1. Avoid obscurity expressions.
2. Avoid ambiguity.
3. Be brief (avoid unnecessary prolixity).

4. Be orderly.

Once a sentence is uttered by the speaker, the hearer chooses the interpretation of the sentence that is the most consistent with the assumption that the speaker has complied with the maxims outlined above. In (1), for instance, Anne's answer leads the speaker to compute some inferences. As we have seen, this sentence should be seen as elliptical for "I like some but not all Mozart sonatas". The reason is that if the speaker had intended to convey the information according to which she likes all Mozart's sonatas, she would have used, to that purpose, the more informative sentence "I like all of them", and the hearer is fully aware of that. More exactly, in Grice's model of communication, the hearer is aware of the fact that not using the more informative variant would bring about a violation of the first submaxim of quantity: "make your contribution as informative as is required". The hearer concludes thus that the speaker's communicative intention involves excluding the possibility that she likes all of Mozart's sonatas. The final result is the speaker's meaning (the so-called pragmatic reading of the sentence), that is, "I like some but not all of Mozart's sonatas", which is clearly distinct from the original meaning conveyed by the sentence (the so-called logical or semantic meaning): "I like some and possibly all Mozart's sonatas".

It is in 1975 that Grice introduced the notion of *implicature* to account for information that go beyond the literal meaning of the utterance. According to Grice, implicatures can be Particularized Conversational Implicatures (PCIs) or Generalized Conversational Implicatures (GCIs). PCIs are strongly dependent on the context, while GCIs are default inferences, which are not strictly bound to the context, but they are related to an appropriate trigger, that is a word. *Scalar implicatures* are the paramount example of GCIs, illustrated by cases such as (2a), which is said to implicate (2c):

(2) (a) She played some Mozart sonatas
(b) She played all Mozart sonatas
(c) She played not all Mozart sonatas

The proposition in (2b) entails the proposition in (2a) because it is more informative. In order to obey Grice's first Maxim of Quantity ("make your contribution as informative as is required"), and make thus an optimal contribution to the common purpose of the conversation, the speaker should utter the most informative proposition (2b) if what he intends is (2b). Hence, according to the Gricean account, when listening a proposition like (2a), (2a) is typically understood as implicating the proposition in (2c), which crucially involves the negation of the proposition in (2b).

This sort of implicature is standardly called *scalar* and traditionally related to the neo-Gricean account found in Horn (1972). *Scalar implicatures* are more or less conventionalized scales of lexical items organized by order of informativeness. Levinson (1983: 134) provides the examples in (3):

(3) < all, most, many, some, few >
< and, or >
< n, …, 5, 4, 3, 2, 1>
< excellent, good >
< hot, warm >
< always, often, sometimes >
< succeed, V ing, try to V, want to V >
< necessarily *p*, *p*, possibly *p* >
< certain that *p*, probable that *p*, possible that *p* >
< must, should, may >
< cold, cool >
< love, like >
< none, not all >

Other lexical scales are, for instance:

(4) < first, second, third, fourth, fifth, … >
< definite, indefinite >
< lover, friend >
< need, want >
< old, middle-aged, young >

< general, colonel, major, captain, … >

The informativeness of scales, as those in (3) and (4), is characterized by the presence of a one-way semantic relation. However, as noted by Hirschberg (1985: 114), scalar implicatures are extremely varied because "the orderings that permit speakers to license scalar implicatures (…) range from those relatively domain-independent "canonical" orderings inspired by the logical quantifiers and connectives to domain-dependent entity rankings – and from linear orderings to hierarchical orderings"; she also claims that "the relations that support scalar implicature (…) turn out to be just the class of partially ordered sets, or posets" (Hirschberg, 1985: 125). This view is shared by Carston (1990, 1997) and Horn (1992), who do not consider scalar ordering as a homogeneous class, even within the range of entailment scales. According to them, numerals have a peculiar behaviour with respect to other scalar terms. Consider, for instance, a sentence like "Christmas is coming in 286 days". Here, it is possible to use numerals with an "at most" reading, though this reading is not possible with other scalar terms, as in *some*. Numerals are usually interpreted with an exact interpretation, thus, they do "not have an "at least" semantics which is upper-bounded by a scalar implicature; rather they might be best analysed as underspecified among the "at least", "exact" and "at most" readings. (…) Scalar inferences associated with numerals would no longer be considered conversational implicatures but would come out as different ways of pragmatically enriching the underspecified semantic content of the numerals" (Papafragou, Musolino, 2003: 259).

From a standard Gricean point of view, scalar implicatures (SIs, henceforth) are firstly computed by the semantic module which assigns the original truth conditions to a sentence; after that, the pragmatic module intervenes, by enriching these truth-conditions. This idea has been challenged by Chierchia (2004) because SIs fail to arise as a global effect in specific linguistic contexts, whereas there are embedded SIs that must be computed before the end of the semantic computation, as it applies to the sentence as a whole. Consider the sentence in (5a):

(5a) Anne is either drinking a coffee or eating some biscuits.

(5b) Anne is either drinking a coffee or eating some biscuits, but she is not eating all the biscuits.

(5c) Anne is either drinking a coffee or eating every biscuit.

(5d) Anne is either drinking a coffee or eating some biscuits and it is not the case that (Anne is drinking a coffee or eating every biscuit).

(5e) Anne is not drinking a coffee.

If we interpret (5a) globally, the alternative relative to the second disjunct, where the implicature is triggered, is (5c), which is more informative than (5a). Under the pragmatic interpretation of (5a), all its stronger alternatives are then denied, most crucially (5c). The new interpretation is thus (5d), which negates the alternative in (5b). But, from this alleged pragmatic interpretation in (5d), we may infer that (5d) obtains (5e); and this is certainly not a correct characterization of the speaker's meaning of (5a). It seems thus that the correct pragmatic interpretation of (5a), that is (5b), should be calculated locally, at the level of the second disjunct, that is, while the semantic processing of the whole sentence is still going on.

The other issue concerning SIs concerns the so-called *downward entailing* contexts. In a context of this type, inferences are licensed from sets to their subsets. For instance, negation is a downward entailing context (DE), since (6a) entails (6b):

(6a) John did not buy a car.

(6b) John did not buy a red car.

DE contexts can be realized also in sentences containing scalar terms, as in (7a) and (7b):

(7a) Anne invited Mary or Paul.

(7b) Anne did not invite Mary or Paul.

The difference in these sentences is the reading of the disjunct *or*. In (7a) it is interpreted exclusively, because the correct reading is that Anne invited either Mary or Paul, but not both (pragmatic reading); while in (7b) the disjunct is interpreted inclusively, meaning that Anne invited neither Mary nor Paul. In (7b), thus, the SI is not calculated and the interpretation that is assigned is the default semantic interpretation, to the exclusion of the pragmatic interpretation. This means that in DE contexts, the SIs that should arise because of the presence of a scalar term tend not to arise, to the effect that the scalar term is interpreted semantically (for instance, *or* is interpreted inclusively, as in propositional logic).

However, there are also cases in which, although the structural context at stake is DE, the SIs arises, as in (8) (Chierchia *et al*, 2004: 287):

(8) It was a two-course meal. But everyone who had skipped the first or the second course enjoyed it more.

In uttering this sentence, it is crucially not meant that a person who had skipped both the first and the second course enjoyed it more, that is, we do not interpret the disjunct *or* inclusively. The right interpretation of (8) is rather that a person who has eaten only the first course or only the second course enjoyed it more. In this case, even if the context is DE, the implicature is calculated, because not doing so would give rise to an unintelligible reading. Thus, in DE contexts, SIs do not arise, unless something forces them to be calculated.

In DE contexts, SIs do not arise because in these contexts the scale of informativeness is generally reversed. If we consider a non-DE context, also called *upward entailing context*, the inference is licensed from sets to supersets. Consider (9):

(9) Mary invited Anne and John.

In this case, this statement is true only if both Anne and John are invited by Mary (the sentence is true in one and only one scenario). By contrast, a statement with the disjunction *or*, as in (10a), is true in three situations, exemplified in (10b), (10c), (10d):

(10a) Mary invited Anne or John.
(10b) Mary invited Anne and John.
(10c) Mary invited Anne.
(10d) Mary invited John.

In fact, (10b) logically entails (10a). Hence, we conclude that (10b) is more informative than (10a). On the contrary, in DE contexts, a statement that includes the disjunction *or* as in (7b), here repeated as (11), is more informative than (12), which involves a conjunction. Thus, (12) is true in three situations as illustrated in (12a), (12b), and (12c):

(11) Anne did not invite Mary or Paul.

(12) Anne did not invite Mary and Paul.
(12a) Anne invited neither Mary nor Paul.
(12b) Anne invited Mary.
(12c) Anne invited Paul.

In upward entailing contexts (UE contexts) a statement which includes *and* is more informative than a statement which includes *or*; on the contrary, in DE contexts, a statement which includes *or* is as informative as *and*, given that the implicature does not arise. In DE contexts, we cannot then proceed to calculate the implicature potentially triggered by *or* by negating the corresponding sentence with and, since the latter is arguably less informative than the former, to the effect that the maxim of Quantity does not dictate the use of the conjunction.

The issues regarding implicatures have been addressed by many scholars, who formulated different accounts. These pragmatic theories are based on Grice's idea that there is a set of expectations that allow the interlocutors to infer the meaning of the sentences involved in a conversational exchange based on the original meaning of the utterance and on the contribution of the context. The main theories can be subdivided in two groups: the so-called Neo-Gricean account (Gazdar, 1979; Horn, 1973, 1984, 1989, 1992, 2004; Levinson, 1983, 2000; Chierchia, 2004), that is relatively close to Grice's formulation; and the Post-Gricean account, whose most important formulation is undoubtedly Relevance Theory (Bezuidenhout, 1997; Blakemore, 1987, 2002; Blass, 1990; Carston, 2002; Carston and Uchida, 1997; Gutt, 1991; Ifantidou, 2001; Matsui, 2000; Moeschler, 1989; Noh, 2000; Papafragou, 2000; Pilkington, 2000; Reboul, 1992; Rouchota and Jucker, 1998; Sperber and Wilson, 1986/1995; Yus, 1997).

Neo-Griceans consider scalar implicatures to be conversational implicatures, and they also propose that some conversational implicatures are strongly dependent on the context, while others, as scalar implicatures, are not. According to Horn (1972), as already mentioned, scalar implicatures depend on the existence of lexical scales. Horn's idea is that, in computing scalar implicatures, the alternatives to be compared are determined by the lexical scale where the scalar terms belong. For instance, if a scalar term like "some" is used in a sentence, the hearer/reader automatically compares the term with the stronger terms that are present in the scale, in this case "all".

Relatively close to Grice's original formulation is the definition of Levinson (2000) of three more general principles stemming from Grice's maxims:

> Q-Principle
> Speaker's maxim. Do not provide a statement that is informationally weaker than your knowledge of the world allows, unless providing an informationally stronger statement would contravene the I-Principle. Specifically, select the informationally strongest paradigmatic alternate that is consistent with the facts.
>
> Recipient corollary. Take it that the speaker made the strongest statement consistent with what he knows.
>
> I-Principle.
> Speaker's maxim. Produce the minimal linguistic information sufficient to achieve your communicational ends.
>
> Recipient corollary: The Enrichment Rule. Amplify the informational content of the speaker's utterance, by finding the most specific interpretation, up to what you judge to be the speaker's m-intended point.

M-Principle

Speaker's maxim. Indicate an abnormal, non-stereotypical situation by using marked expressions that contrast with those you would use to describe the corresponding normal, stereotypical situations.

Recipient corollary. What is said in an abnormal way indicates an abnormal situation, or marked messages indicate marked situations.

These principles allow us to interpret sentences as in (1), here repeated in (13):

(13) Bill: Do you like Mozart sonatas?
Anne: Some of them.

In the elliptical answer of Anne, Bill interprets her answer as complying with the I-Principle, by producing the minimal linguistic information sufficient to achieve her communicative purpose. In (13), Bill also assumes that Mary is obeying the Gricean Maxim of Relation. This justifies the way he analyzes the answer, that is, by enriching the content of her utterance. Moreover, according to the Q-Principle, Bill understands that Mary made the strongest possible statement consistent with her knowledge.

In the interpretation of scalar implicatures, Levinson (2000) further proposed that the scalar term, in its pragmatic interpretation, is lexicalized as its default interpretation. He considers that in the pragmatic interpretation, the scalar term is encoded as a defeasible part of its meaning, that is, "some" also means "not all". The semantic interpretation, where "some" is interpreted as "at least one", is accessible only if the pragmatic interpretation is explicitly negated.

Relevance Theory (Post-Gricean account) is still based on Grice's two foundational ideas, but the differences from the standard account are mostly related to the expectations that guide the comprehension process. In the case of Griceans and neo-Griceans, these expectations come from principles and maxims, because they expect speakers to obey or occasionally violate rules of communication. These violations may be unavoidable because of a clash between two different maxims, or they may be committed on purpose as a dedicated instrument in order communicate to the hearer some implicit meaning: the speaker knows that the hearer will calculate an implicature as the result of the detected maxim violation. For Relevance Theory, the speaker, in the very act of communicating, raises in his interlocutors precise and predictable expectations of relevance, which guide the hearer to the speaker's meaning. Even if Grice proposed the Maxim of Relation, invoking relevance, he did not define it in a fine-grained way; Relevance Theory, on the contrary, starts from a detailed account of relevance and its role on cognition. Relevance is defined as a property of inputs, that include external stimuli and mental representations, with respect to cognitive processes. These inputs are relevant when they connect to background knowledge to yield new cognitive effects, which amount to changes in the assumptions of a cognitive subject. The changes result from the processing of an input in a context of previously held assumptions. The processing of the input may lead to three possible different cognitive effects, that are, the derivation of new assumptions, the modification of previously held assumptions, or the deletion of previously held assumptions. Relevance is the possibility to achieve such cognitive effects; it is, thus, what makes an input worth processing. Inputs may differ on the cognitive costs and on how much they are relevant and more worth processing. For instance, when a doctor utters a sentence like "you caught a flu", this utterance carries more cognitive effects, and is thus more relevant, than a sentence like "you are ill". Some mental effort is required when processing this sort of inputs. An example of input that is relevant and with a smaller processing effort is a sentence like "you caught a flu" when compared to "you have a disease spelled with the sixth, the twelfth and the twenty-first letter of the alphabet" (Noveck, Sperber, 2004). Relevance, thus, deals with the degree assigned to these two factors: direct proportionality with cognitive effect, and inverse proportionality with processing effort.

In Relevance Theory, there are two principles about the role of relevance in cognition and communication (Noveck, Sperber, 2004: 6):

> *Cognitive principle of relevance.* Human cognition tends to be geared to the maximization of relevance.

> *Communicative principle of relevance.* Every act of communication conveys a presumption of its own optimal relevance.

Unlike Gricean and neo-Gricean maxims and principles, these two principles are not intended as normative but as purely descriptive. The Cognitive Principle of Relevance predicts that the human perceptual mechanisms pick out spontaneously potentially relevant stimuli, the human retrieval mechanisms activate spontaneously relevant assumptions, and the human inferential mechanisms process them spontaneously in the most productive way. To do so, however, the speaker needs an audience that is focused on the relevant communicative purpose. In order to obtain a successful conversation, the speaker wants his utterance to be seen as relevant by the audience: this is in fact what the Communicative Principle of Relevance states.

In the Relevance Theory the presumption of optimal relevance (Noveck, Sperber, 2004: 6) conveyed by every utterance grounds a specific comprehension heuristic:

> *Presumption of optimal relevance*
>
> (a) the utterance is relevant enough to be worth processing.
>
> (b) it is the most relevant one compatible with communicator's abilities and preferences.
>
> *Relevance-guided comprehension heuristic*
>
> (a) follow a path of least effort in constructing an interpretation of the utterance (and in particular in resolving ambiguities and referential indeterminacies, in going beyond linguistic meaning, in computing implicatures, etc.).
>
> (b) stop when your expectations of relevance are satisfied.

For instance, in (1), in evaluating Anne's answer "some of them", the listener follows a path of least effort and perceives "them" related to Mozart sonatas, and the whole sentence to be elliptical for "I like some of them". The attention of the listener is plausibly gained by the fact that Anne is answering his question. However, the expectations of relevance are not yet satisfied. Anne was in fact able, but chose not to do so, to answer that she liked all Mozart sonatas. Giving not the *all*-answer ("I like all of them"), the listener is entitled to interpret that she likes only some of them. Now, the expectations of relevance are satisfied.

Concerning scalar implicatures, Relevance Theory considers them to be explicatures rather than conversational implicatures, as neo-Griceans do. According to Relevance Theory, scalar implicatures are the result of a pragmatic enrichment of the logical form of a sentence. This enrichment process is the same as for other sorts of utterances, such as metaphors, loose talk, etc. If, for instance, someone says "It's freezing outside", this sentence is usually interpreted "It is very cold outside". The interpretation of the sentence comes through a process that is driven by the context because the concept is constructed locally on the meaning of "freezing". This construction is a contextually driven non-linguistic, conceptual process (de Carvalho *et al.* 2016). This is one point of crucial difference from the neo-Gricean approaches. In Relevance Theory, in fact, scalar implicatures are interpreted through a process that is identical to the one mentioned, that is one of *ad hoc* concept construction. Moreover, this process is cognitively costly, meaning that differently from what suggested by neo-Griceans, scalar implicatures are costly and they are accessed only if the context makes them relevant. Summing up, regarding scalar implicatures, the main point for the post-Gricean account is the central role assigned to the context. It is through contextual processes that it is possible to calculate scalar implicatures, and lexical scales are not assigned any specific role.

Neo-Gricean and post-Gricean accounts differ not only theoretically, but also for the different experimental predictions they make.

For neo-Griceans, the semantic interpretation is costlier than the pragmatic interpretation. On the post-Gricean account, the opposite is true, that is, semantic interpretation is less costly than the pragmatic interpretation. This means that if there is a costly interpretation, this would be acquired later in cognitive development, and, regarding reaction times, it should take more time to be processed. Thus, for neo-Griceans the semantic interpretation should come later and take more time to be processed, while for post-Griceans, it is the pragmatic interpretation that is acquired later and takes more time to be processed. Several works that contrasted the predictions of the neo-Gricean and post-Gricean accounts have provided robust evidence in favour of the post-Gricean account, because it has been proved that children acquire later the pragmatic interpretation (see section 3.1.1) and reaction time measures in adults show that the pragmatic interpretations of scalar terms takes more time to be processed than semantic interpretations (see section 3.1.2). Moreover, the amount of pragmatic answers given by adults was strongly context-dependent (see Hartshorne *et al.* 2015 and Dupuy *et al.* 2016) and this is contradiction with Levinson's default account. In his account, Levinson implies that all underinformative sentences with scalar terms should be given pragmatic interpretations and that the implicature is explicitly negated when the sentence is semantically interpreted. Thus, since now, all the experimental results favour for the post-Gricean account contradicting the predictions of the neo-Gricean accounts.

Based on experimental work that we are going to explore in the next section, Chierchia (2013) has proposed a new version of the neo-Gricean account. In his theory, he considers scalars, free-choice implicatures, polarity items, upward and downward entailing contexts. For what concerns scalar implicatures, Chierchia considers them to be the "result from a covert exhaustification operator (roughly equivalent in meaning to *only*) that operates on a set of alternatives determined by the scale the scalar term belongs to" (de Carvalho & Reboul *et al.* 2016: 3). The problem with this idea is that the set of alternatives is only available to the exhaustification process if the context makes it mandatory to derive the implicature. Consider for instance the conversational exchange below:

(14a) Bill: Did you play *all* Mozart sonatas?
(14b) Anne: I played *some* Mozart sonatas.
(14c) Anne: I played *most of* Mozart sonatas.
(14d) Anne: I played *all* Mozart sonatas.

(15) Bill: Did you play Mozart sonatas?

In (14a) the question leads to a set of possible alternatives, including *most* and *all*, as illustrated in (14b), (14c) and (14d); in (15) the alternative set would not be available because of the absence of the covert exhaustification operator in (15). As noted by Chierchia (2013), the central contextual factor in the derivation of scalar inferences is the relevance to conversational goals.

In the recent version of Chierchia, some differences between the neo-Gricean approaches and the post-Gricean approach disappear, even if Chierchia does not take any explicit position regarding processing costs of implicatures. In his new approach, he considers context to play a central role. However, the alternatives that play a role in scalar implicatures are entirely discharged on Horn scales, which are lexically determined.

The theories discussed above, Grice's original theory, the neo-Gricean theory and Relevance Theory, are not the only theoretical approaches to pragmatics. As reported in Noveck, Sperber (2004: 7), important contributors to pragmatic theorizing with original points of view include Anscombre and Ducrot (1995); Bach (1987, 1994); Bach and Harnish (1979); Blutner and Zeevat (2003); Dascal (1981); Ducrot (1984); Fauconnier (1975, 1985); Harnish (1976, 1994); Kasher (1976, 1984, 1998); Katz (1977); Lewis (1979); Neale (1990, 1992, forthcoming); Recanati (1979, 1988, 1993, 2000); Searle (1969, 1979); Stalnaker (1999); Sweetser (1990); Travis (1995); Van der Auwera, J. (1981, 1985, 1997); Vanderveken (1990-91); see also Davis (1991), Moeschler and Reboul (1994).

3.1 Experimental works on the computation of Scalar Implicatures

Experimental works on linguistic-pragmatic issues are relatively recent. However, there are some classical reasoning studies (Braine, Rumain, 1981; Evans, Newstead, 1980; Paris, 1973; Smith, 1980; Sternberg, 1979) that give us interesting results. When adults are presented sentences in a pragmatically infelicitous context, they are often equivocal in answering. For example, in Evans and Newstead's (1980: 382) second experiment, the authors presented the participants "a series of sentences, followed by a letter and a number. The task (was) to say whether the sentence is true or false with respect to the letter and number presented". The participants saw, for example, a sentence like "either there is a P or a 4" in some possible situations: when there is a P with a 4, a P with a 9, or a Q with a 4, etc. When the sentence contained the conjunction *and* (presented as "P 4"), the authors reported that this type of sentence was considered true for the 57 per cent of the participants, while it was considered false for the 43 per cent of the participants. The same pattern of results has been reported in Paris (1973). Here, the group of adults responded true in weak contexts in 67.5 per cent of the cases.

Other interesting results come from developmental studies. Children are more likely than adults to provide logically correct responses. In Paris (1973), 90 per cent of the 8-year-old participants accepted as true cases where both disjuncts were true. This developmental result has been confirmed by many other studies, such as Braine, Rumain, 1981, Sternberg, 1979 (on propositional connectives) and Smith, 1980 (on quantifiers).

Sternberg (1979: 492), after confirming Paris' results, claims that "the data show an interesting interaction between age and interpretation of *or* … children at the lowest grade level use the inclusive interpretation of *or* in preference to the exclusive interpretation … At the higher-grade levels, children show a strong tendency to use the exclusive interpretation in preference to the inclusive interpretation". As noted by Noveck (2004: 305), what fails to be observed is the explanation of this effect. According to him, weak terms, such as *or*, *some* and *might*, have a linguistically encoded meaning that is compatible with minimal interpretations of underinformative items, while pragmatic inferences increase with age. The minimal interpretation corresponds to the logical one, while pragmatic enrichment seems to be quite exclusively a prerogative of adults.

In the next sections we are going to deepen the analysis of the experimental works on scalar implicatures, both on children and on adults.

3.1.1 The computation of Scalar Implicatures: developmental studies

The studies of Paris (1973), Braine and Rumain (1981), Sternberg (1979) and Smith (1980) opened a new field of investigation. Many scholars are in fact studying the developmental-pragmatic effect. Noveck (2001) started investigating children's responses to weak scalar utterances through two different experiments. In Experiment 1 he studied how children reason in a modal-context, while in Experiment 3 how do they behave in a context with quantifiers.

In Experiment 1, Noveck (2001) proposes a reasoning scenario which involves three boxes, the first two (Box A and B) opened, the last (Box C) closed. In Box A there is a parrot and a toy bear, in Box B there is only a parrot. Seven-year-old participants are told that in Box C there is the same content as either in Box A or in Box B. A puppet presents eight statements and the participants are asked to say whether the puppet's claim is right or not. The target sentence is *There might be a parrot in the box*, a clearly underinformative sentence with respect to the statement *There must be a parrot in the box*. 80 per cent of the answers of seven-year-olds participants is consistent with the logical interpretation, whereas adults tend to draw out the pragmatic potential of the sentence. According to Noveck (2001: 174), it is the case that "logical interpretation of *Might* remains the default and they (the children) give way to pragmatic interpretation".

In Experiment 3, the original paradigm of Smith (1980) was employed with little variations. Noveck (2001) tested children at the age of 8 and of 10 and he compared their answers to adults'. In this experiment there were six kinds of statements based on the existential quantifiers *some* and *all*, and three kinds of relations: absurd (e.g. Some chairs tell time/All crows have radios), appropriate (e.g. Some houses have bricks/All elephants have trunks) and inappropriate (e.g. Some giraffes have long necks/All dogs have spots). Target sentences are those in the inappropriate condition with the quantifier *some*. The results showed that 85 per cent of children's answers were compatible with underinformative statements, and thus, they are consistent with Smith's results.

Similar findings have also been found in other experiments such as Papafragou, Musolino (2003); Chierchia, Guasti, Gualmini, Meroni, Crain and Foppolo (2004); Guasti, Chierchia, Crain, Foppolo, Gualmini and Meroni (2005).

Papafragou and Musolino (2003) were interested in whether young children compute scalar implicatures as adults do. They tested children at the age of 5 in two experiments on scalar implicatures using different types of scales. The scales employed in the experiments involve quantificational expressions, i.e. <all, some>; number terms, i.e. <three, two>; and inchoative/completion predicates, i.e. <finish, start>. In the first experiment, participants were presented, among others, sentences as "Some of the horses jumped over the fence", in a context where the truth condition is satisfied, but it is pragmatically infelicitous. The results show a different pattern of results between adults and children. As in previous studies, in fact, while adults tend to reject underinformative statements, children almost never did so. What is more interesting, in Papafragou and Musolino (2003), is Experiment 2. Differences from the first study are a pre-test training and more and specific instructions. The authors wanted children to be strongly aware of the pragmatic infelicity, rather than judge truth. Specifically, children were told that a puppet would say "silly things" and their role in the game was to help the puppet to say it better. In the case children did not correct the puppet, the experimenter did. Another difference is a modification on the stories represented, in order to support the implicatures in a much stronger way, focusing on the protagonist's performance. The results show that children's sensitivity to scalar implicatures is strongly improved if they are firstly presented the goals of the task and if they are provided a context that more readily invite pragmatic inferences.

After this study, Guasti, Chierchia, Crain, Foppolo, Gualmini and Meroni (2005), wanted to investigate whether training has a long-lasting effect. In the first experiment they replicated Noveck's (2001) finding, with children providing a high percentage of "logical" answers. In Experiment 2, Guasti *et al.* (2005) tested seven-year-old children who, prior to the experiment, participated in a training session as in Papafragou, Musolino (2003). During the training, children were made aware of the pragmatic in-/felicity of the sentences by indicating which of the two ways that described the picture constituted the better option. At the end of the training session, the experimenter reminded every child of the differences in describing sentences and, during the experiment, if the child did not agree, she would occasionally be invited to explain why. Looking at the results, children who participated in the training session gave a higher number of rejection to statements like *Some giraffes have long necks*, in comparison to children who did not attend the training session. The rejection rate was 12 per cent for children without training, while for those who have been trained, the percentage rose to 52 per cent. More interestingly, Guasti *et al.* (2005), in Experiment 3, investigated whether the enhancement of performance achieved through training is permanent. One week after Experiment 2, children were re-tested, without replicating the training session. "The main finding is that children who rejected the critical *some* statements after training (Experiment 2) failed to do so when retested without additional training … On average, therefore, the effect of training did not persist" (Guasti, Chierchia, Crain, Foppolo, Gualmini and Meroni, 2005: 683).

As noted in the theoretical section, there are contexts in which scalar implicatures do not arise, as in Downward Entailing contexts. Chierchia, Crain, Guasti, Gualmini, Meroni (2001) and Gualmini, Meroni, Crain (2003) explore what happens when children deal with these contexts with respect to scalar implicatures. Chierchia *et al.* (2001), using a Truth Value Judgment Task (Crain, McKee, 1985; Crain, Thornton, 1998) tested 4-year-old English children with sentences with the logical connective *or* in the first or in the second argument of *every*. The target sentence for a DE context is, for instance, (16a), while (16b) is the target sentence for a non-DE context (Chierchia *et al.* 2001:164-165):

(16a) Every dwarf who chose a banana or a strawberry received a jewel.

(16b) Every boy chose a skate-board or a bike.

The authors expected children to consistently access the inclusive-*or* reading of the disjunction operator. For a sentence like (16a), the experimenter performed a story about Snow White and four dwarves at a picnic. Snow White invites every dwarf to choose healthy food, reminding them that banana and strawberry are healthy food. If the dwarves will choose healthy food, she promises to reward them with a jewel, otherwise she will not. Three of the dwarves want to receive a jewel so they choose healthy food, but, being very hungry, they choose both the banana and the strawberry. One of the dwarves is not interested in the jewel, so he chooses potato chips. Snow White, as promised, rewards only the dwarves who have chosen a banana and a strawberry. At the end, a puppet produces the utterance in (16a). As noted by Chierchia *et al.* (2001: 164-165), "it is important to observe that the target sentence is true only if the disjunction operator *or* is interpreted under the inclusive *or*-reading. Therefore, if children (or adults), compute scalar implicatures, and then interpret the target sentence under the (derived) exclusive-*or* reading of disjunction, they should reject the puppet's assertion". A story for the sentence in (16b) featured four boys who are choosing a toy to play with. They can choose among skate-boards, bicycles, a boat and a truck. After considering the possibilities, the four boys choose to pick up a skate-board and a bike. At this point, the puppet utters (16b).

Results show that in the first type of sentences, those exemplifying a DE context, children and adults have similar results. Children accepted target sentences for 91.6 per cent of time; the control group of adults, accepted them as true for 95.5 per cent of time. They both, thus, "access the inclusive-*or* reading of disjunction when this occurred in the restrictor of the universal quantifier *every*, a downward entailment environment" (Chierchia *et al.* 2001: 165). Different results emerge when a non-DE context is presented. In this case, children acceptance was 50 per cent, while for adults it was 0 per cent.

These results are interesting in showing how the behaviour of children differs according to the context. If, in fact, children are presented with a DE context, their answers are adult-like. It is thus the case that these results are consistent with the view according to which the computation of implicatures comes at a cost. In DE contexts, instead, children reach adult performance since implicatures do not arise.

The same pattern of results is confirmed by Gualmini, Meroni and Crain (2003). In a Truth Value Judgment Task, they tested five-year-old children on the disjunction operator *or* with the scheme of downward entailment. Children and the control group of adults were presented with short stories and what emerged is that "children, like adults, interpret the disjunction operator *or* in the internal argument of the universal quantifier *every* in accordance with the interference scheme typical of downward entailing operators. (…) the findings reveal a striking asymmetry between children's interpretation of the disjunction operator *or* in the two arguments of the universal quantifier" (Gualmini, Meroni, Crain, 2003: 145).

Another point of interest in the literature on the computation of scalar implicatures from the developmental point of view concerns the observation made by Papafragou, Musolino (2003: 276), according to which "children are more likely to infer an enriched interpretation in an adult-like manner when the context makes this enrichment highly relevant".

This claim has been proved by some other scholars. Feeney, Scrafton, Duckworth, Handley (2004), in Experiment 2, investigate whether the sensitivity of children to scalar implicatures using the quantifier *some* is increased when the context is pragmatically enriched. In this experiment, some storyboards are presented to twenty-eight English children in a range of age between seven-year-old and eight-year old. In each of these storyboards, there is a girl performing an action with some or all of the objects in the scene. In each situation, the experimenter read a statement made by the girl that describes the action. She, according to the experimental condition, claims to have interacted with some or all the objects. Children are asked to indicate whether the statement is true or false. To make the story more "real", the statement made by the girl is always an answer to her mother and the behaviour preceding it was likely to have been proscribed. Thus, the context motivates the girl to conceal the truth from her mother. When given the appropriate contexts, in fact, children draw the standard scalar implicature associated with *some*.

The same claim has been made by Papafragou, Tantalou (2004). They tested thirty Greek-speaking children at the age of five. The context consisted in the presentation of a set of animals and the children were told that they would play a game. Children had to reward the animal who performed a specific task previously assigned. In this experiment different scale types were employed: quantificational (*all, some*), encyclopaedic (which included a set of orderings licensed by world knowledge, and supported by the context), or ad hoc (which introduced a range of circumstantial, context-specific orderings). Papafragou, Tantalou (2004: 75-76) specifies that "the experimental scenarios resemble naturalistic communicative circumstances in which implicatures are actually computed". Results show that children correctly withheld to reward the animals 77.5 per cent of the time in the quantificational cases, 70 per cent in the encyclopaedic cases and 90 per cent in the ad hoc cases. After providing their responses, children were asked to justify them. It is interesting to note that when children refuse to give the prize to the animal, they justify their choice by claiming that a "weaker" scalar term was used, instead of a stronger one. Thus, the authors claim that "in contexts that approximate naturalistic conversations, children are capable of assessing informativeness expectations built during a talk exchange and of deriving SIs when these expectations are not met by the speaker's conversational contribution" (Papafragou, Tantalou, 2004: 77-78).

Guasti, Chierchia, Crain, Foppolo, Gualmini and Meroni (2005) also tested children in a more natural context. The authors wanted to control the situation and, thereby, to establish the conditions that are a prerequisite for the computation of scalar implicatures. In order to do so, they opt for a Truth Value Judgment Task (Crain, Thornton, 1998). Fifteen Italian-speaking children, mean age 7;2 participated in the study and they were asked to judge five statements with the quantifier *some* that were logically true, but underinformative. The main finding is that the performance of children nearly resembles that of the adults. Children, in fact, had a rejection rate of 75 per cent, while adults 83 per cent. This difference is not significant.

The experiments just mentioned (Feeney, Scrafton, Duckworth, Handley (2004), Papafragou, Tantalou (2004), Guasti, Chierchia, Crain, Foppolo, Gualmini and Meroni (2005)), show that employing different materials and procedures has a strong effect in developmental studies on scalar implicatures. Thus, it is the case that children are very sensitive to training and task manipulation.

Foppolo, Guasti and Chierchia (2012) ran six experiments trying to assess the boundaries of age in deriving scalar implicatures. In a Truth Value Judgement Task (Experiment 1), the authors showed that children from age 6 have an excellent pragmatic performance. This is not the case for younger children at age 4 and 5 because they reject only occasionally underinformative statements. This performance is interesting, given that in pragmatic tasks, such as the Conversational Violations Test and the Felicity Judgment Task (respectively, Experiment 4 and 5), they perform very well. Foppolo *et al.* (2012), in fact, highlight that in the Statement Evaluation Task in Guasti *et al.* (2005), seven-year-old children's behaviour show a bimodal distribution, and, the fact that in Foppolo *et al.* (2012) children are split into two groups, in the processing of SIs, might suggest that the process of maturation is not completed yet for all the children at the age of 5.

To test the performance rate, Foppolo *et al.* (2012) manipulate the experimental design by adding the partitive *alcuni dei* (*some of*) in Experiment 2; in Experiment 3, they prime the scale <some, all> by showing children, prior to the critical underinformative statement with *some*, a correct statement with *all*; in Experiment 6 the authors stressed the ambiguity of *some* in order to make children more aware of it.

With respect to Experiments 2 and 3, there was no improvement on children's behaviour in the derivation of SIs. As claimed by Foppolo *et al.* (2012: 390) "the absence of such an improvement, (…), might suggest that children's difficulties are not to be found at the level of pure lexicon or lexical access".

On the contrary in Experiment 6, after enhancing awareness in children in the informativeness of the statements, the authors found a significant improvement. The rate of rejection of underinformative statements with the quantifier *some* was 72.5 per cent, which has never been attested in the literature for five-year-old children in a Truth Value Judgment Task. Foppolo *et al.* (2012: 391) suggest that "children's failure in deriving the SI related to *some* might be linked to other "cognitive" difficulties manifested by children in other tasks". Considering the results globally, the authors suggest that there are three factors that might play a role when children process sentences with underinformative *some*. The first is the maturation of the lexicon because, in the case of scalar items, two layers of representation are involved: the lexical entry in its basic meaning and the scale. The process that link these two must be firstly acquired and then automatized. The second factor is the ability to shift one's strategy and perspective. As shown by tests of executive functions (Bialystok, Martin, 2004; Bialystok, Senman, 2004), this ability is not mature yet at the age 5, even if it can be improved by specific tasks and with explicit/implicit instructions that enhance children's awareness of the ambiguity, as shown by Gopnik, Rosati (2001). The last factor is the influence of the task, the materials used for the experimental protocol and design used for the test. As seen from the results mentioned above of Evans, Newstead (1980), Paris (1973), Sternberg (1979), Braine, Rumain (1981), Noveck (2001), Papafragou, Musolino (2003), Chierchia, Guasti, Gualmini, Meroni, Crain and Foppolo (2004), and Guasti, Chierchia, Crain, Foppolo, Gualmini and Meroni (2005, Experiment 1), if children are presented with a Truth Value Judgment Task, they are more likely to give logical answers; in DE contexts, in Chierchia, Crain, Guasti, Gualmini, Meroni (2001) and in Gualmini, Meroni, Crain (2003) they have an adult-like behaviour; while, when given the appropriate context, as in Feeney, Scrafton, Duckworth, Handley (2004), Papafragou, Tantalou (2004) and Guasti, Chierchia, Crain, Foppolo, Gualmini, Meroni (2005, Experiment 4), children are capable to draw scalar implicatures. As claimed by Foppolo *et al.* (2012: 392) "in any case, the large variability observed across different studies that employ a similar methodology reaffirms once again that children are very sensitive to subtle changes in the way the task is conceived and administered and extremely vulnerable to flaws in the experimental design". Differently from what stated in Guasti *et al.* (2005), children are not, according to Foppolo *et al.* (2012), more logical than adults. Moreover, Katsos and Bishop's proposal (2011) of "pragmatic tolerance" of children, which explains why they over-accept underinformative statements, does not take under consideration that if children are given best chances to be pragmatic, they do so without failing.

According to the approaches presented in the previous section, the neo-Gricean approach and Relevance Theory, all in all the results are more compatible with Relevance Theory. The predictions made by these accounts are, in fact, quite different. While neo-Griceans consider semantic interpretation to be more costly to process than the pragmatic interpretation, and, thus, to occur later in the development, for post-Griceans the opposite is true. When given the appropriate context, children can derive the implicature. On the contrary, in Truth Value Judgment Task, when children are asked to compute sentences like *Some elephants have trunks*, they tend to respond logically. The pattern of answers changes over time, resulting in a more adult-like behaviour. Interestingly, however, when children are presented a DE context, they do not manifest any problem in the interpretation of scalar terms.

All these data are compatible with Relevance Theory's predictions, since pragmatic answers tend to occur later across developmental stages.

3.1.2 The computation of Scalar Implicatures: adult studies

It can be argued that children's data are different from adults' only because children are not reliable subjects to be tested, as far as it concerns implicatures computation, since their processing resources are still developing. In order to obtain other classes of data that could support one or the other theoretical approach on the computation of scalar implicatures, different studies on adults have been carried out. To provide evidence in favour of the default inference view on the neo-Gricean account, results should show that pragmatic interpretations are simpler than semantic interpretation (which involve circumventing the default reading) and trigger lower reaction times. On the contrary, if the Relevance Theory is supported by adults' data, it should turn out that the semantic interpretations are simpler, triggering lower reaction times, and that the pragmatic enrichment occurs later.

Noveck and Posada (2003) ran an interesting experiment on scalar implicatures on adults. In this study, the authors collected time of responses and ERP data on a set of sentences that were patently true, patently false and underinformative. In the latter case, sentences can be true or false according to whether the subject chooses the semantic or the pragmatic interpretation.

Underinformative sentences were formed only with the quantifier *some*, as in *Some dogs have ears* (Noveck, Posada, 2003). Reaction-time data are interesting because the authors found that there was a difference between the participants who responded true to underinformative sentences and those who judged the sentence as false. When participants chose false, they took nearly twice as long as when they chose true (655ms was the mean time for those who gave semantic answers and 1203ms for those who gave pragmatic answers). Moreover, participants who answered 'yes' to underinformative statements were faster also in responding correctly to the other conditions, the patently true and patently false sentences. The authors suggest that this behaviour reflects two sorts of strategies: those who accept underinformative statements tend to interpret literally scalar items, and thus they perform quicker; whereas participants who consider these statements false have in fact opted for a non-literal interpretation, which requires more time, which shows that they are engaged in a more complex reasoning.

The ERP data are interesting too, because they show that underinformative items generally led to a flat N400, which indicates that there is little semantic integration. For control conditions, that are patently true and patently false, the N400 was even flatter. The evoked potential N400 was elicited in a comparable way both for participants who responded True to underinformative items and for those who responded False. According to Noveck (2004: 318), "the scalar inference, which requires more effort and prompts participants to respond False, is part of a late-arriving, effort-demanding decision process".

Another interesting study was carried by Bott and Noveck (2004), who ran four experiments investigating the time course of underinformative sentences like *Some elephants have trunks*. The starting point of Bott and Noveck (2004) was a study conducted by Rips (1975), which was one of the earliest psychological studies to investigate the conflicting interpretations of underinformative sentences like *Some congressmen are politicians*. He asked participants to make category judgments and examined the effect of the interpretation of the quantifier through two experiments. In one of these experiments he asked participants to interpret *some* as *some and possibly all*, whereas in the second experiment he asked them to interpret *some* as *some but not all*. When results were compared, Rips (1975) noted that participants who received the *some but not all* instructions were slower than those who received the *some and possibly all* instructions.

The experimental design of Bott and Noveck (2004) was drawn from Smith (1980) and Noveck (2001), and it was based on Rip's findings. In their experiments, the authors included six kinds of sentences on the form *[Quantifier] A are B* with the <some, all> quantifiers. The set of relationships between A and B was A as a subset of B (as in *Some/All monkeys are mammals*), B as subset of A (as in *Some/All mammals are monkeys*) and another condition where A and B formed two disjoint sets (as in *Some/All monkeys are fish*). Experiment 1 was a replication of Rips (1975, Experiments 2 and 3) and was split into two sessions. In one experimental session, participants were instructed to interpret the quantifier *some* as *some and possibly all*, while in the other experimental session the same quantifier had to be interpreted as *some but not all*. We thus refer to the first case as the Logic condition, and to the other as the Pragmatic condition. The results show that when participants were in the Pragmatic condition, and were thus instructed to draw the implicature, they needed more time to evaluate Underinformative sentences; on the contrary, in the Logic condition, they were faster. The data also show that it was more difficult to answer correctly when they were instructed to derive the implicature. Participants were, in fact, accurate on 85 per cent of the underinformative sentences under Logic instructions and accurate on about 60 per cent on the underinformative items under Pragmatic instructions.

Interesting data also come from Experiment 3 in Bott and Noveck (2004). In this experiment, the authors used the same paradigm as in Experiment 1 but neither instructions nor feedback were given to participants. It was expected to have two groups. One group of participants would spontaneously draw the implicature (the Pragmatic group), the other would not (the Logic group). In this case, Bott and Noveck (2004) could compare the answers of the groups as did in previous experiments. The authors' main finding is that pragmatic answers have a longer mean reaction time than the logic answers. We conclude that also in this experiment the findings of the previous experiments are confirmed.

In Experiment 4, Bott and Noveck (2004) combined the procedure of Experiments 1 and 3. Sentences were presented one word at a time and no instructions nor feedback was given to the participants. The aim of this experiment was to confirm or disconfirm the predictions from Relevance Theory concerning the processing of scalar implicatures. One of the dependent variables in this experiment was the time available for the response. In one condition (Long Condition) a long time to respond was made available to the participants (3000msecs), while in the other condition (Short Condition), participants were given a short time to respond (900msecs). By manipulating the time available, the authors attempted at limiting the cognitive resources available to the participants in order for them to provide the appropriate answer. According to Relevance Theory, participants should answer with a quick "True" in the short condition; on the contrary, when participants have more time to answer, they should give more "False" responses. The results, interestingly, show that for experimental conditions in the short conditions there were significantly more logical responses to underinformative sentences. This trend supports the predictions made by Relevance Theory.

Similar findings have been reported by Katsos, Breheny, Williams' (2005), in Experiments 2, and 3. In Experiment 2, the authors ran an on-line reading time experiment, recorded in a segment by segment self-paced reading paradigm. Material for the experiment was made of sentences in two conditions: upper-bound (UB), as in (17) and lower-bound (LB) context (18):

(17) UB: The manager asked: Who has the report on last year's profits? Her secretary replied: Jones or Barnes from the department of Finance has. Would you like to see the report?

(18) LB: The manager asked: Who has a report on last year's profits to show me? Her secretary replied: Jones or Barnes from the department of Finance has. Would you like to see the report?

Katsos *et al.* (2005: 1111) found that "the critical segment, "Jones or Barnes", was read in 819ms in the upper-bound and in 775ms in the lower bound condition" suggesting that the computation of scalar implicatures is actually costly.

In Experiment 3 the authors replicated the findings that drawing scalar implicatures is a time-consuming process, by using ad hoc scales that are introduced by the discourse context, as <roof, house>, <father, parents>.

In another study, Bott, Bailey and Grodner (2012) investigated the costs for deriving implicatures. In Experiment 1, the authors tested participants on the comprehension of UB sentences and LB sentences when they could not trade off speed for accuracy. In agreement with Bott, Noveck's findings (2004), they found that correct UB sentences take longer response time in comparison to LB sentences. In Experiments 2 and 3, Bott, Bailey and Grodner (2012) wanted to rule out semantic complexity differences, and compared thus the quantifier *some* in its pragmatic and logical meaning to its explicit equivalents, that are *only some* in Experiment 2, and *at least some* in Experiment 3. The main finding is that pragmatic-*some*, relative to the explicit control, is delayed in the interpretation more than in its interpretation of logical-*some*. All these results are "the first to provide evidence of the costs associated with deriving implicatures *per se*" (Bott, Bailey, Grodner, 2012: 123).

In confirmation of this claim, the time-enriched pragmatic effect has been studied also in disjunctions. The sentential connective *or* can be, in fact, interpreted either inclusively (A or B or both) or exclusively (A or B, but not both). Chevallier, Noveck, Nazir, Bott, Lanzetti and Sperber (2008), following Bott and Noveck (2004), Noveck (2001) and Noveck and Posada (2003) wanted to investigate whether extra effort is applied to disjunctive statements. Chevallier *et al.* (2008) ran three experiments. In Experiment 1, the one we are interested in, participants saw a five-letter word and they were required to respond with a Yes/No answer to statements such as *There is an A or a B*. The authors manipulated the time available for the response. While in the control condition, the letter string remained visible, in one experimental condition the five-letter string was removed before the descriptive sentence appeared (short time condition), while in the other experimental condition the minimal amount of time necessary for answering was extended, in order to trigger further processing. The authors wanted participants to apply more cognitive resources when interpreting the disjunction. To attract their attention, they increased the saliency of the word, writing it capitalized and underlined. Findings show that when participants are encouraged to respond within a second, participants give a high number of Logical responses (84 per cent). On the contrary, when participants can answer whenever they want, giving them an unlimited amount of time to decide, their rates of Logical answers drop to around 55 per cent. According to Chevallier *et al.* (2008: 1751) "this implies that they (the participants) were more likely to derive the enriched interpretation when they were encouraged to spend more time processing the sentence than when they were not encouraged to do so".

All the results of the studies reviewed above are interpretable in the relevance theoretic framework because minimal interpretations serve as the basis for quick judgments, while Pragmatic responses arrive subsequently. We conclude that the cognitive chronometry studies on adults strongly confirm Relevance Theory's predictions, and closely match the results obtained in the developmental studies reviewed in an earlier section.

4. Experimental Protocols

4.1 Introduction

In this chapter I will present the experimental protocol that I developed to test the predictions of the SSIRH with respect to pragmatic computations, reporting the description of the participants (section 4.2.1), the procedures adopted in Experiment 1 (section 4.3.2) and in Experiment 2 (section 4.4.4), the research questions and predictions for Experiment 1 (section 4.3.3) and for Experiment 2 (section 4.4.5), and the results and the discussions of the experiments (respectively sections 4.3.5 and 4.3.6 for Experiment 1 and sections 4.4.7 and 4.4.8 for Experiment 2).

In both Experiment 1 and Experiment 2 I tested, with adults, the computation of scalar implicatures with a musical background in order to verify whether the presence of music affects the cognitive/linguistic process of implicature calculation. From previous studies, as discussed above, we know that there seems to be an interaction in the processing of linguistic and musical syntax (see chapter 1).

As far as I know, there are no experimental results, to the contrary, concerning a possible interaction of language and music in the wider cognitive perspective made available by experimental pragmatics. This provides the main motivation for these experimental protocols. The purpose of this study is to explore whether language and music interact at the level of pragmatic processing that corresponds to implicature computation, and, if they do, to verify whether the results vary according to the participants' musical expertise.

4.2 Methods

4.2.1 Participants

Participants were the same for both Experiment 1 and Experiment 2. I recruited them at the University of Verona and at the Conservatorium of Verona. Unless participants wished otherwise, all were paid 10€ for participation. The payment was possible thanks to the "Scuola di Dottorato in Scienze Umanistiche" of the University of Verona.

42 participants were tested, and I divided them into 2 groups: 20 musicians (henceforth, M) and 22 non-musicians (NM). Among the M, 5 were males, 15 females; among the NM 8 were males, 14 females. As in Morrison *et al.* (2003: 379) I defined NM those who had "fewer than 2 years of participation in an instrumental or choral ensemble and less than 1 year of private performance instruction". Basic instruction given at ordinary schools was not considered. All NM reported they had not studied music outside ordinary lessons at school. As in Patel *et al.* (1998), M had significant musical experience (*M*= 9 years, *SD*= 5.3) and played one or more musical instruments. In the group of musicians 6 play the piano, 1 piano and harp, 1 piano and flute, 1 piano, guitar and bass, 1 piano and organ, 1 piano, organ, harpsichord and violin, 2 violin, 1 clarinet, 1 viola, 1 guitar, 1 guitar and piano, 1 guitar and violin, 2 western concert flute.

The age range for both groups is 19-32, with M (*M*= 23.2 years, *SD*= 3.9) and NM (*M*= 23.2, *SD*= 3.4). A one-way ANOVA with Group (M and NM) as an independent variable confirmed that there were no significant age differences between the groups, $F(1,40)= .001$, $p = .976$. All participants were Italian native speakers. No bilinguals were tested, even if all participants reported they had studied one or more foreign language at school. Moreover, all participants reported no linguistic, auditory, psychiatric or neurological disorder. Their vision was normal or corrected to normal. Prior to the experiment, participants were asked to answer the Edinburgh Handedness Inventory (Oldfield, 1971). Answers were analyzed thanks to http://www.brainmapping.org/shared/Edinburgh.php and the result considered was the Laterality Index for each respondent. Main lateralization quotient was 60 for M and 53.6 for NM. A one-way ANOVA with Group (M and NM) as an independent variable shows that there were no significant differences in lateralization between both groups, $F(1,40)= 1.285$, $p = .264$. Thus, participants in each group were right-handed.

4.3 Experiment 1 – Statement Evaluation Task

The first experiment is a statement evaluation task with linguistic manipulated difficulty (computation of scalar implicatures, that is pragmatically felicitous vs. pragmatically infelicitous sentences) and the presence/ absence of musical background. In particular, participants were presented with a written sentence on a screen, which appeared at fixed time one word at time. Concomitantly to the sentence presentation, the participants heard a chord played by a synthesized piano. Participants, divided in two groups, musicians and non-musicians, were asked to answer whether they agreed or disagreed with the sentence, based on their encyclopaedic knowledge. I measured accuracy and RT. The task included four experimental conditions: pragmatically felicitous and infelicitous sentences without music stimuli and pragmatically felicitous and infelicitous sentences with music in tune in the background. Additionally, I added six different types of filler: sentences with the universal quantifier in true and false context (with and without musical background) and true and false declarative sentences (with and without musical background).

4.3.1 Design and materials

Experiment 1 has a 2×2 within-subjects and within-items design, manipulating linguistic complexity (felicitous vs. infelicitous sentences) and the absence or presence of musical stimuli.

The language materials consisted of 10 felicitous sentences, 10 infelicitous sentences (both sets involving the quantifier *some*), 10 fillers with the quantifier *all* in true context, 10 fillers with the quantifier *all* in false context, 20 fillers consisting of declarative sentences without quantifier in a true context and 20 fillers consisting in declarative sentences without quantifier in a false context. Each of these groups were a half without any musical stimuli and a half with musical background. The length of linguistic stimuli was 11 words for each sentence in each condition. An example of felicitous sentence is given in (1), of infelicitous sentence in (2), of sentence with *all* true in (3) and of *all* false in (4), of a declarative sentence without quantifier in a true context in (5) and in a false context in (6). All stimuli can be found in Appendix A.

1. La signora Elena Zacchi dice che alcuni quadrupedi sono dei cavalli.
   Ms. Elena Zacchi says that some quadrupeds are horses.
2. La signora Giada Vinco dice che alcuni incisivi sono dei denti.
   Ms. Giada Vinco says that some incisors are teeth.
3. La signora Noemi Pasci dice che tutti i molluschi sono invertebrati.
   Ms. Noemi Pasci says that all the molluscs are invertebrates.
4. Il signor Alfio Costa dice che tutti gli alberi sono betulle.
   Mr. Alfio Costa says that all the trees are birches.
5. Il signor Muzio Pasco dice che la luna è un satellite.
   Mr. Muzio Pasco says that the moon is a satellite.
6. La signora Irina Tozzo dice che il sole è un pianeta.
   Ms. Irina Tozzo says that the sun is a planet.

Musical stimuli included 40 items, all in the tonality of C major. All musical stimuli were mainly between the second and the fifth register (octave) of the piano. Pitches ranged from B1 to A5 and they were played at 80bpm, a rate of presentation that, according to Akiva-Kabiri, Vecchi, Granot, Basso and Schön (2009) is a rate of presentation of musical stimuli in between slow and fast. All sequences were played by the piano in the midi version of Finale notepad2008 and, in order to ensure no familiarity with the music, they have been specifically composed with Finale notepad2008 for this experiment. The melodies were 12 s in length.

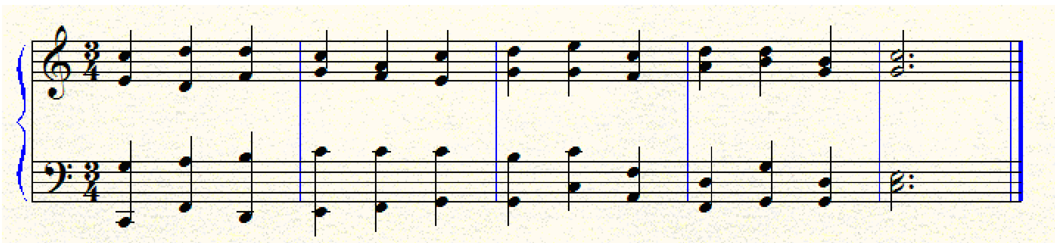
Musical sequences were in a tempo of ¾ and were composed of 5 bars, each of them included three crotchet chords, except for the last one which had a chord with a duration of ¾. The total amount of chords in each musical sequence was 13 chords.

Stimuli were presented in a one-word-one-chord fashion and, in order to ensure the establishment of musical tonality, all linguistic sentences started in a very similar way, such as "Mr. So-and-so says that…" (see examples from 1 to 6 above). The quantifiers *some* and *all* occurred always in the seventh position, which always coincided with the tonic chord, that is the tonal center in the musical scale and which establishes the hierarchical reference for all other chords. The position was also rhythmically relevant because it coincided with the strongest beat of the bar in which it occurred. Other fillers had the same musical characteristics, having the same tempo and the same tonality, but the tonic chord did not necessarily occur in the seventh position. Below I report one musical sequence for the linguistic condition with *some* (7) and one for a filler declarative sentence (8). In Appendix A the reader can find all musical stimuli.

7.

La signora Elena Zacchi dice che **alcuni** quadrupedi sono dei cavalli
(Ms. Elena Zacchi says that some quadrupeds are horses)

8.



Il signor Nereo Gatti dice che il dado ha sei facce
(Mr. Nereo Gatti says that the dice has six faces)

All musical stimuli were composed with Finale notepad2008, then exported from midi to wav version with Cubase5 (DAW software) by Steinberg. Items containing both linguistic and musical information were created in a video format through Windows Live Movie Maker.

4.3.2 Procedure

The experiment took place on an individual basis in a quiet experimental room. Before the experimental session, participants were asked to fill the Edinburgh Handedness Inventory (Oldfield, 1971), and to sign a written informed consent form. After that they were presented with instructions, here reported (Italian and English versions) and were then invited to sit in front of a computer screen.

Questo è il primo test della durata di 15 minuti. Non appena premerai la barra spaziatrice, comparirà sul monitor una frase del tipo "Il signor Tal dei Tali dice che il tonno è un pesce" oppure "La signora Pinco Pallo dice che Tokyo si trova in Austria". Tu dovrai rispondere se sei d'accordo o in disaccordo con quanto affermato dai personaggi. Dovrai premere il tasto **n** se sei in disaccordo, il tasto **b** se sei d'accordo. Ti chiedo di usare la sola mano destra per rispondere.
Al termine di ogni tua risposta, comparirà la scritta "Premere la barra spaziatrice". Se sei stanco, quindi, puoi fare una pausa, se invece premi la barra proseguirai con il test.
Mentre leggerai le frasi, noterai che ogni tanto ci sarà della musica di sottofondo. Ti chiedo di non prestarci attenzione e di rispondere alla frase (linguistica) indipendentemente dalla musica di sottofondo.
Ti chiedo inoltre di rispondere il più velocemente ed accuratamente possibile.

(This is the first test and it lasts 15 minutes. As soon as you press the space bar, it will appear on the screen a sentence like "Mr. So-and-so says that tuna is a fish" or "Ms. So-and-so says that Tokyo is in Austria". You have to say whether you agree or disagree with what asserted by the characters. Press button **n** if you disagree, press button **b** if you agree. I ask you to use only the right hand to answer.
After giving your answer, it will appear the sentence "Press the space bar". If you are tired, you can have a pause, otherwise press the space bar and the test will carry on.
While reading the sentences, you will notice that sometimes there will be music in the background. I ask you not to take care of it and to answer to the (linguistic) sentence regardless the music.
I also ask you to answer as fast and as accurate as possible.)

The sentence remained on the screen until participant's response, however participants were asked to perform as rapidly and as accurately as possible. Dependent variables were RTs and error rates. When participant responded, the target disappeared from the screen and the sentence "Press the space bar" appeared instead, thus participants could make a pause at the end of every item. There was no training before the Experiment, and items were randomized. The programme used for the Experiment was E-prime 2.0, which presented the stimuli and recorded the answers (both RT and accuracy). Participants used headphones to listen to the musical stimuli. The usage of E-prime 2.0, the headphones and of the quiet experimental room was possible thanks to Prof. Silvia Savazzi and the Department of Neurosciences, Biomedicine and Movement Sciences of the University of Verona.

4.3.3 Research questions and predictions

The main interest of Experiment 1 is related to the simultaneous processing of linguistic sentences and musical sequences. I wanted to evaluate whether the presence of music interferes with linguistic processing, and if it does, whether the interference is modulated by the complexity of the linguistic condition, that is, pragmatically felicitous vs. infelicitous sentences. More particularly, I wanted to test the prediction according to which the presence of music affects linguistic processing in the most difficult linguistic condition, that is the pragmatically infelicitous condition.

Independently of the issue raised by music/language interaction, I also tested the difficulty of computing scalar implicatures. Here, I predict that, in accordance with the experimental results reviewed above, supporting Relevance Theory, pragmatically infelicitous sentences should be more difficult to compute, both in terms of RTs and in terms of accuracy.

My last research question concerns the possible differences between musicians and non-musicians. As in Poulin-Charronat *et al.* (2005) and Slevc *et al.* (2009), this is an implicit task because I do not require explicit attention to the musical stimuli. According to the literature, when no explicit attention is required, no differences between the groups are found, thus I do not expect substantial differences.

4.3.4 Data analytic plan

I conducted the analysis through a mixed-design ANOVA (2×2×2) both for accuracy and for reaction time. In both cases the within-subject factors were

Language (some felicitous and some infelicitous) and Music (without music and with music in tune in the background); Group (musicians and non-musicians) was the between-subjects factor. In the analysis of accuracy, Mauchly's test indicated that the assumption of sphericity had been violated for both Language, Music and the Language × Music interaction ($\chi 2(0) = .000$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .62$). In order to understand the interaction between Language and Music, I ran two paired-samples *t*-tests. When underinformative sentences (i.e. pragmatically infelicitous ones) were interpreted pragmatically they were judged "false"; as a consequence, "true" answers in this condition were considered as errors (i.e. they were considered equivalent to interpreting the sentence logically, and not pragmatically).

In the analysis of reaction time, 15.72% of total answers has been discarded because they were errors, and another 2.86% of answers was discarded because they were outliers. I have considered as outliers those answers with less than 120msec or more than 5000msec of reaction time. RTs below 120ms reflect anticipatory responses prior to proper stimulus processing, while I assumed that responses after 5000ms reflect distraction. For the remaining trials, I checked RTs outside of the interval defined by the intra-subject average ±2.5 standard deviation, in order to minimize the impact of outliers on mean RT. However, nobody was outside this range. I then calculated the average for each participant in each of the different conditions prior to the calculation of the grand average over all participants. Mauchly's test indicated that the assumption of sphericity had been violated for both Language, Music and the Language × Music interaction ($\chi 2(0) = .000$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .91$). Also in RT analysis I ran paired-samples *t*-tests in order to explore the Language × Group interaction.

4.3.5 Results

A mixed-design ANOVA (2×2×2) was carried out on accuracy for each condition, with Language (some felicitous, and some infelicitous, hereafter indicated respectively as SF and SI) and Music (without music and with music in tune in the background, hereafter respectively indicated as NO, and MI) as within-subject factors, and Group (musicians and non-musicians) as a between-subjects factor. Hereafter, I am going to refer to the experimental conditions as SFNO for some felicitous without musical background, SFMI for some felicitous with music in tune, SINO for some infelicitous without music and SIMI for some infelicitous with music in tune in the background. I also refer to Groups as M for musicians and NM for non-musicians.

Groups are not significantly different ($F(1,40)= 2.491$, $p = .122$), with a medium effect size (partial $\eta^2 = .059$). I found a main effect of Language ($F(1,40) = 48.098$, $p < .001$). The strength of this result, as indexed by partial η^2, was large (partial $\eta^2 = .55$) indicating that the two linguistic conditions are processed differently. Post hoc comparisons with Bonferroni correction indicated that the mean error rate for the SF condition (see Tables 1 and 2) was significantly lower ($p < .001$) than the score for the SI condition. This result reveals overall the increased difficulty in the infelicitous condition, in which the scalar implicature has to be computed, with a higher number of errors compared to the felicitous condition for both groups.

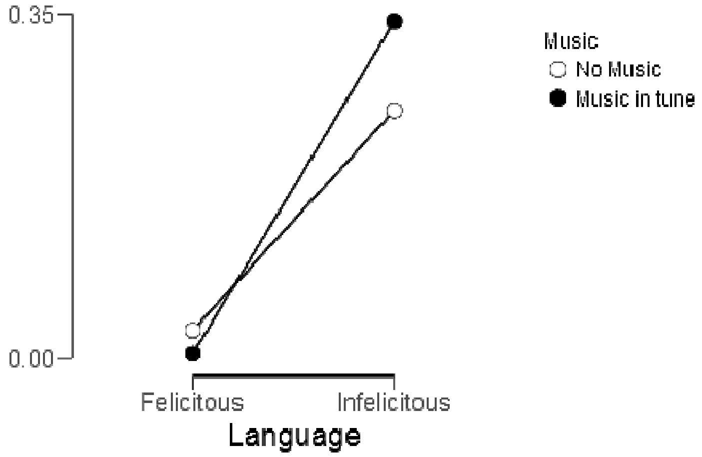
Table 1, *Descriptive plot for Language SF Vs. SI*

Language	Mean	SD
SF	.016	.007
SI	.295	.039

Table 2, *Post hoc with Bonferroni correction for Language (SF - SI)*

Language	Language	SD	Sig.a
SF	SI	.040	.000
SI	SF	.040	.000

The effect of Music was not significant ($F(1,40)= 3.533$, $p = .067$), with a medium effect size (partial $\eta^2 = .081$), even though there was a significant Language × Music interaction ($F(1,40)= 6.427$, $p = .015$), with a large effect size (partial $\eta^2 = .138$), indicating that the presence of music differently affected the two linguistic conditions (see Graph 1).



1. This graph shows the increased error rate for the linguistic conditions with and without musical background.

In order to understand the interaction between Language and Music, I ran two paired-samples *t*-tests. Both groups (M and NM) were considered together, given the absence of a significant effect for Group. SFNO and SFMI did not statistically differ ($t(41)= 1.704$, $p = .096$), indicating that the presence of music does not affect performance in felicitous contexts. A significant difference was instead observed in the scores for SINO and SIMI ($t(41)= -2.304$, $p = .026$), suggesting that in the pragmatically infelicitous contexts the presence of music in the background affects the performance of both groups (see Tables 3 and 4 below). In other words, it is only in the infelicitous condition that it is possible to observe a decreasing accuracy when music is played in the background.

Table 3, *Descriptive plot of the t-tests SFNO Vs. SFMI and SINO Vs. SIMI, Exp. 1*

		Mean	N	SD
Pair 1	ACC SFNO	.029	42	.0835
	ACC SFMI	.05	42	.0309
Pair 2	ACC SINO	.252	42	.2761
	ACC SIMI	.343	42	.2940

Table 4, *Paired-samples t-tests SFNO Vs. SFMI and SINO Vs. SIMI, for accuracy in Experiment 1*

		Mean	SD	*T*	df	Sig.
Pair 1	ACC SFNO - ACC SFMI	.024	.0906	1.704	41	.096
Pair 2	ACC SINO - ACC SIMI	-.0910	.2545	-2.304	41	.026

Summarizing, for both groups the infelicitous condition was more difficult to process, as testified by significantly lower accuracy. Moreover, the Language × Music interaction revealed that in the infelicitous sentences the accuracy significantly decreased in presence of music.

The remaining interactions were not significant: Neither Language × Group was significant ($F(1,40)= 1.465$, $p = .233$, partial $\eta^2 = .035$), nor Music × Group ($F(1,40)= 1.918$, $p = .174$, partial $\eta^2 = .046$). Also Language × Music × Group was not significant ($F(1,40)= .904$, $p = .347$, partial $\eta^2 = .022$). All these results indicate that both groups behave the same in the Language, Music and in Language × Music conditions.

To analyse reaction times, I ran the same statistical model. In this analysis Language was not significant ($F(1,33)= 3.302$, $p = .078$, partial $\eta^2 = .091$), and so were Music ($F(1,33)= 1.147$, $p = .292$, partial $\eta^2 = .034$), and Group ($F(1,33)= 1.253$, $p = .271$, partial $\eta^2 = .037$).

Conversely, the Language × Group interaction was significant ($F(1, 33)= 4.415$, $p = .043$) with a medium effect size (partial $\eta^2 = .118$) indicating that groups react differently to the linguistic conditions and that the linguistic conditions are in fact different from each other. To better comprehend this interaction, a paired-sample *t*-test has been conducted for each group separately comparing SF to SI considering the mean of SFNO and SFMI in the SF condition and the mean of SINO and SIMI in the SI condition.

In the group of M the mean score of the SF condition does not significantly differ from the mean score of the SI condition ($t(19)= -1.262$, $p = .222$). However, in the group of NM a significant difference is observed between the SF condition and the SI condition ($t(21)= -2.506$, $p = .020$). In other words, the presence of longer reaction times in the infelicitous condition found for NM reveals, with respect to this group, an increased difficulty in the computation of scalar implicatures.

All other analysis were not significant. The mixed-design ANOVA did not show a significant effect of Music × Group ($F(1,33) = .190$, $p = .666$, partial $\eta^2 = .006$), of Language × Music ($F(1,33) = .085$, $p = .772$, partial $\eta^2 = .003$), and of Language × Music × Group, ($F(1,33) = .528$, $p = .473$, partial $\eta^2 = .016$).

All in all, these results show that, concerning accuracy, the pragmatically infelicitous sentences are more difficult to be processed than the felicitous ones, for both groups. The Language × Music interaction shows that music interferes with language processing. Both groups are, in fact, significantly less accurate when there is a musical background than in the condition without any musical stimuli. However, this effect is significant only in the infelicitous conditions, while no significant differences are found in the felicitous conditions.

As for the reaction time analysis, in the paired-sample *t*-test following the Language × Group interaction, the group of NM shows that the pragmatically infelicitous condition is more difficult to process than the pragmatically felicitous. This confirms the results obtained from the accuracy analysis, at least for what concerns the non-musicians.

4.3.6 Discussion

From a linguistic perspective, Experiment 1 confirms the Relevance Theory's predictions. The responses to pragmatically infelicitous sentences are significantly less accurate than the responses to the pragmatically felicitous sentences. Moreover, concerning RTs, the group of NM confirmed that the pragmatically infelicitous condition is the most difficult condition to be processed. This is showed by the increased RTs exhibited by this group with respect to the pragmatically felicitous condition.

At the level of Language and Music interaction, the predictions I wanted to test were (i) that there was a language/music interference and (ii) that this interference was modulated by linguistic complexity. Specifically, I expected to find an effect of music only in the most difficult condition, corresponding to the sentences featuring infelicitous *some* (as it occurred in the works of Fedorenko *et al.*

2009, Slevc *et al.* 2009 and Hoch *et al.* 2011 for the most difficult linguistic conditions related to syntax). This is exactly what I found: according to the results presented above, music significantly affects meaning computation only in the infelicitous contexts (i.e. in the most difficult contexts). Moreover, I also found group differences: although all subjects were less accurate in pragmatically infelicitous sentences, non-musicians were also slower in reacting to these kind of sentences in comparison to musicians (see section 2.7 for group differences).

However, there is an important limitation in the value of these results. They abstract away from the reasons why music should affect meaning computation in linguistic processing. In Experiment 1, I tested whether meaning computation interferes with Music at a general level, but I would like to deepen the analysis by testing whether music interferes with meaning computation in a different way when it is in tune, when it is presented in the form of an out-of-key chord or when it is presented in the form of an augmented chord concomitant to the scalar item. In other words, the question is now: is it possible to single out the aspects (i.e. properties) of musical processing that trigger the interference with meaning computation? Moreover, there is also an independent methodological limitation in the experimental design that I should try to circumvent. The statement evaluation task of Experiment 1, based as it is on world knowledge, independently requires longer times for processing, since meaning computation is also based on the subject's ability to perform information retrieval from an encyclopaedic data base, a cognitively costly independent process. Clearly, I should strive towards experimental conditions that guarantee that the cognitive/linguistic processing that possibly interferes with musical processing is strictly limited to the process of computing a pragmatic reading with respect to the process of computing a logical reading. A sentence/picture evaluation task is arguably the best way to get rid of this sort of experimental artefacts. This is thus exactly what I tried to do in Experiment 2.

4.4 Experiment 2 – Sentence Picture Verification Task

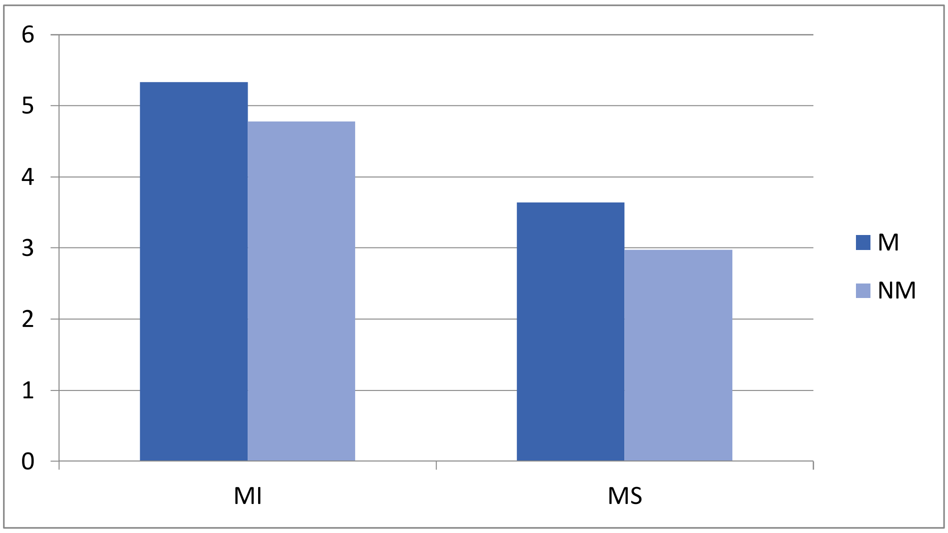
In the Sentence Picture Verification Task, I manipulated linguistic difficulty through the computation of scalar implicature (felicitous vs. infelicitous sentences) and musical complexity (without musical stimuli (NO), with music in tune in the background (MI), with music with the out-of-key chord (MS), with music with the augmented chord (Aug)).

In particular, participants were presented with a picture on a screen and then, below the picture, a written sentence appeared one word (or chunk of words, phrase, relative clause) at a time. Concomitantly to the sentence presentation, a chord played by a synthesized piano was presented. The time of presentation was fixed in order to have a clear musical sequence. As in Experiment 1, participants, divided in two groups, musicians and non-musicians, were asked to answer whether they considered true or false the sentence that referred to the picture on the screen. I measured accuracy and RT. The task included eight experimental conditions: pragmatically felicitous and infelicitous sentences varying the musical background: NO, MI, MS and Aug. Additionally I added eight different types of filler: sentences with the universal quantifier in true and false context without musical background, MI, MS and Aug.

4.4.1 Preliminary study

Prior to the actual conduction of the experiment, I wanted to be sure that both groups of participants were sensitive to the out-of-key chord. Therefore, I tested 15 M (mean of musical practice= 9.2) and 16 NM (who never had private music lessons, or studied music as autodidacts), different from those who took part in the experimental session. Participants were tested on an individual basis and listened to every musical stimulus belonging to the in-tune and of the out-of-key sets of stimuli. They were asked to judge how harmonious they found the musical stimuli on the basis on a Likert's scale from 1 (absolutely not harmonious) to 7 (highly harmonious).

Age range for both groups was 20-32, with M (*M*= 25.8 years, *SD*= 5.6) and NM (*M*= 23.7, *SD*= 4.75). A one-way ANOVA with Group (M and NM) as an independent variable confirmed that there were no significant age differences between the groups, $F(1, 30)= 2.432$, $p = .13$. Moreover, a paired-sample *t*-test conducted on each group separately and comparing music in tune and out of key revealed a significant difference between the MI and MS condition for both groups. As for M, $t(14)= 7.703$, $p <.001$, and for NM, $t(15)= 6.869$, $p < .001$. Thus, I can conclude that both groups perceive in the same way the absence/presence of the out-of-key chord.



2. Histogram showing the mean for MI (columns on the left) and for MS (columns on the right) in both groups. M: dark blue; NM: light blue.

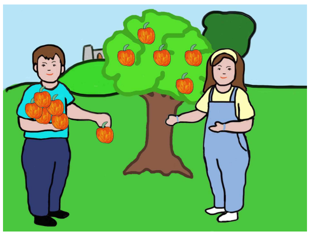
4.4.2 Design and materials

Experiment 2 has a 2×2×4 within-subjects and within-items design, manipulating linguistic (felicitous vs. infelicitous sentences) and musical complexity (NO, MI, MS and Aug).

Linguistic stimuli are 32 pragmatically felicitous sentences and 32 pragmatically infelicitous sentences both with the scalar quantifier *some*. Fillers are 32 true sentences and 32 false sentences both with the universal quantifier *all*. Each of these conditions and fillers has 8 items without musical background, 8 items with music in tune in the background, 8 items with the out-of-key chord concomitant to the scalar item, and 8 items with the augmented chord concomitant to the scalar item. Every linguistic stimulus is presented together with a picture, which the sentence refers to. An example of the pair containing a linguistic felicitous sentence and its concomitant picture is given in (9), an example of an infelicitous sentence and its picture is given in (10), examples of true and false sentences with their relative pictures, respectively in (11) and (12). All linguistic stimuli with their relative numbered pictures can be found in Appendix B.

9. La vecchietta – in blu – ha – alcuni – dei – gatti – che vedi
   The old lady – in blue – has – some – of the cats – that you see

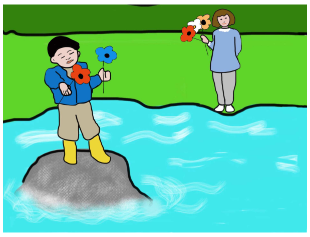
10. Il – bambino – ha – alcune – delle mele – raccolte – che vedi
    The – little boy – has – some – of the harvested – apples – that you see



11. Il – bambino – ha – tutti – i – palloni – che vedi
    The – little boy – has – all – the – balls – that you see

12. Il – bambino – ha – tutti – i – fiori – che vedi

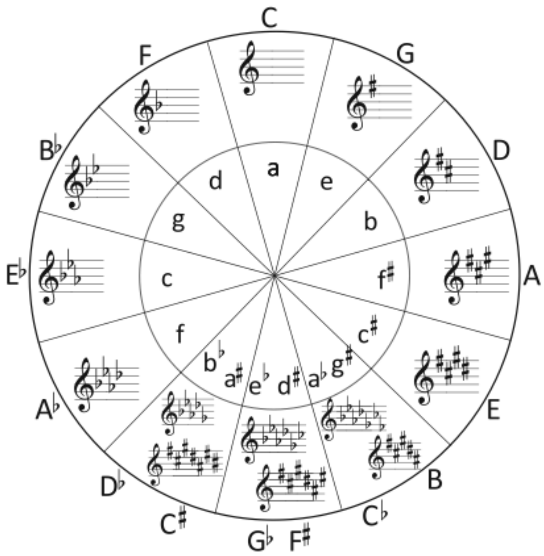
    The – little boy – has – all – the – flowers – that you see



As one can see, at the end of every sentence, I inserted the relative clause "che vedi" ("that you see") for two reasons. The first reason has to do with the music stimuli and the need to create a cadence with a tonic chord in closure, since I have, in this experiment as well as in the preceding one, a presentation that is one-word-(or chunk of words)-one chord. The other reason relates to the need of disambiguating the sentence, in order to refer only to the picture and not to anything else.

Musical stimuli included 72 items, all in the tonality of C major. All musical stimuli were mainly between the second and the fifth register (octave) of the piano. Pitches ranged from B1 to B5 and they were played at 80bpm, considered, from a work of Akiva-Kabiri, Vecchi, Granot, Basso and Schön (2009) a rate of presentation in between slow and fast. All sequences were played by the piano in the midi version of Finale notepad2008 and, in order to ensure no familiarity with the music, they have been specifically composed with this program for this experiment. The melodies were 8 s in length. Musical sequences were in a tempo of ¾ and were composed of three bars, each of them included three crotchet chords, except for the last bar which had a chord with a duration of ¾. The total amount of chords in each musical sequence was of 7. The target chord, which could be in tune, out-of-key, or augmented of 10dB, fell always in the fourth position of the musical sequence. It was always concomitant to the target quantifier, either *some* or *all*. This position is relevant because it occurs after the establishment of the tonality and it is on the strongest beat of the second bar.

Out-of-key chords were determined by the circle of fifths and I always considered the C# major chord as the out-of-key chord for this experiment. This is five steps backwards from the C chord that it is consider acoustically very far from C#, even if they are adjacent in frequency.



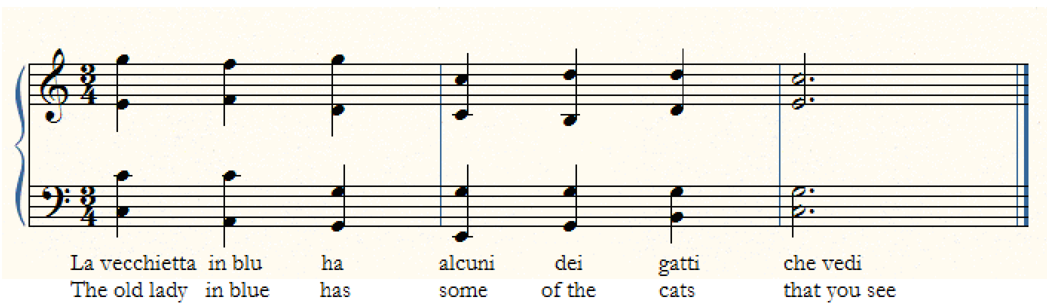
33. Circle of fifths. Elements three places or more away from the original key are considered out-of-key.

As noted by Patel (2008: 246) "this contrast between the physical and psychological proximity of pitches is likely to be part of what animates tonal music".

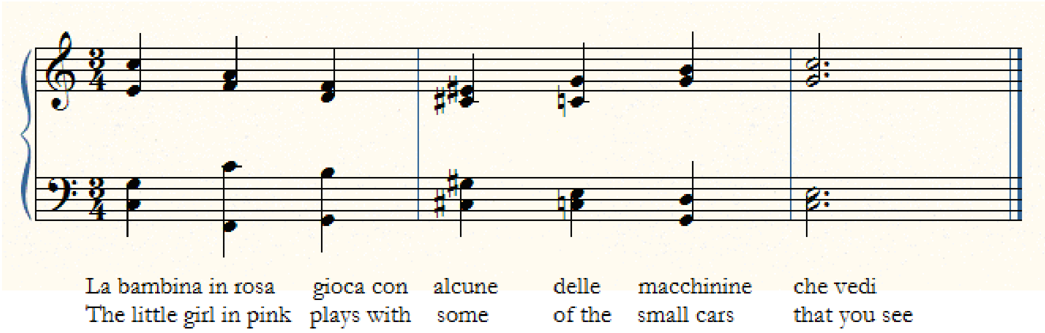
For the loudness manipulation I augmented of 10dB the tonic chord concomitant to the scalar item (that is always in the fourth position) as did Fedorenko *et al.* (2009). Decibel in augmented chords were increased through Cubase 5 (DAW software) by Steinberg.

Below, I provide an example of in tune musical background (14) and of musical background with the out-of-key chord (15). All musical stimuli are provided in Appendix B.

14.



15.



All musical stimuli were composed with Finale notepad2008, then exported from midi to wav version with Cubase5 (DAW software) by Steinberg. Items containing both visual (sentence and picture) and musical information were created in a video format through Windows Live Movie Maker.

4.4.3 Pilot Test

Before conducting the actual experiment, I tested some participants (others from those involved in the actual experiment) on the full set of materials. This pilot study revealed a methodological limitation of the originally proposed experimental design. Participants were instructed to answer as fast and as accurate as possible but only at the end of the presentation of the stimuli. Since, however, the time of presentation was relatively long, participants had enough time to process the sentence prior to its end, thus the test, as it was presented, gave no reliable results. I have found this problem both with respect to reaction times accuracy. Given this problem and given that the sentences had basically the same structure, to the effect that it was unnecessary to read the whole sentence before giving a correct answer, I decided to ask the participants to answer as soon as they felt they were in the condition to do so.

4.4.4 Procedure

Participants were tested individually in a quiet room. Experiment 2 immediately followed Experiment 1, even if all participants were allowed to have a break between the experiments if they wanted to. They were then presented with instructions, here reported (Italian and English versions).

In questo test, della durata di 20 minuti, leggerai delle frasi che saranno sempre accompagnate da un'immagine. La verità o la falsità della frase sarà sempre associata a quel che vedi. Per rispondere dovrai premere i tasti **b** o **n**. Il tasto **n** corrisponde a falso, il tasto **b** a vero. Ti chiedo di usare la sola mano destra per rispondere.
Al termine di ogni tua risposta, comparirà la scritta "premere la barra spaziatrice". Se sei stanco, puoi fare una pausa, se invece premi la barra proseguirai con il test.
Ti avviso: vedrai che riuscirai ad anticipare la risposta senza attendere di leggere tutta la frase. Ti chiedo quindi di non aspettare di leggere tutto, ma di rispondere non appena avrai capito.
Anche in questo test, la risposta va data il più velocemente ed accuratamente possibile.

(In this test, that lasts 20 minutes, you will read some sentences that are always associated with a picture. The truth or the falsity of the sentence is always linked to the picture you see. In order to answer, you will have to press **b** or **n**. Button **n** is for false, button **b** for true. I ask you to use only the right hand to answer.
After giving your answer, there will appear the sentence "Press the space bar". If you are tired, you can have a pause, otherwise press the space bar and the test will continue.
I warn you: you will be able to anticipate the answer of the statement before reading the whole sentence. I ask you not to wait to read all the sentence, but to answer as soon as you understand.
Also in this test, answers must be given as fast and as accurate as possible).

Stimuli were firstly presented in the form of the picture related to the sentence. This picture appeared alone for the first 2 seconds, then the picture remained on the screen and linguistic stimuli started to be visually displayed. The sentence was presented below the picture simultaneously to the musical sequence in a speed of 80bpm. As previously noted, linguistic material was not always one-word-one-chord, but it could also be presented in a chunk-of-words-one-chord fashion (a phrase, a relative clause, or other). After the appearance of a (chunk of) word(s), these remained on the screen, in order not to overload memory capacity. As a sentence was completely displayed on the screen, it remained there until participant's response, though participants were asked to perform as rapidly and accurately as possible. Music material was listened to through headphones. Dependent variables were RTs and accuracy. After the participant gave her answer, the target disappeared from the screen and the sentence "Press the space bar" appeared instead, so that participants could pause if they wanted to at the end of every item. Items were randomized. The programme used for the Experiment was E-prime 2.0 and through this I recorded RTs and error rate. E-prime, headphones and the quiet room were kindly provided by prof.ssa Silvia Savazzi and the Department of Neurosciences, Biomedicine and Movement Sciences of the University of Verona.

4.4.5 Research questions and predictions

In Experiment 2 I tested the computation of scalar implicatures on a different task, that is a sentence picture verification task. As in Experiment 1, I wanted to verify whether infelicitous sentences were processed differently from felicitous ones, predicting that the computation of scalar implicatures is costlier in the pragmatically infelicitous condition (the linguistically/cognitively complex condition) than in the pragmatically felicitous condition.

I also tested whether musicians and non-musicians have a different performance on this task. As in Experiment 1, this is an implicit task, thus I do not expect substantial differences between the groups.

The last research question I am interested in is related to the interference between linguistic and musical processing. In Experiment 2, with respect to Experiment 1, I added two more musical conditions, the condition with the out-of-key target chord, and the condition with the augmented target chord. The loudness manipulation has been inserted because, as in Fedorenko *et al.* (2009: 3), "in order to argue that linguistic and musical integrations rely on the same/shared pool of resources, it would be important to rule out an explanation whereby the musical effect is driven by shifts of attention due to any non-specific acoustically unexpected event. To evaluate this possibility, I added a condition in which the melodies had a perceptually salient increase in loudness instead of an out-of-key (chord) at the critical position".

Here is my experimental hypothesis. Essentially, I predict that, according to the SSIRH, there should be no interference between the most difficult linguistic condition (i.e. the pragmatically infelicitous condition) and the musical stimuli with the out-of key chord. The reason is that implicature computation is not a sort of syntactic processing, but involves non-syntactic linguistic abilities and more general cognitive resources (cf. Relevance Theory). Moreover, I expect that there should be no difference, in computing the implicature in the pragmatically infelicitous sentences, between the two different musical conditions, that is, the condition with the musical background in tune and the condition with the dissonant target chord. The reason is that modulating the degree of musical difficulty (from in-tune chord to dissonant chord) should not interfere with the linguistic/cognitive resources necessary to process implicatures. In fact, according to the most direct interpretation of the SSIRH, complex linguistic processing should be increasingly affected by progressively augmenting the degree of musical difficulty only in the case where the difficulty linked to musical and linguistic processing is essentially of a syntactic nature. This condition is not satisfied by the kind of linguistic/cognitive computation triggered in Experiment 2, since the resources activated in the computation of *some* in infelicitous sentences are clearly non-syntactic in nature. Conversely, if the relationship between linguistic and musical processing could be extended to neural networks beyond those activated, in language, by exclusively syntactic processing, contrary to what is hypothesized by the SSIRH, I would expect that the pragmatically infelicitous condition presented simultaneously with the musical condition involving a dissonant target chord should result the most difficult condition, thus revealing a degree of interference between language and music that is not limited to syntactic processing. In other words, modulating the degree of difficulty in musical processing should affect the form of complex non-syntactic processing corresponding to the meaning of infelicitous *some*.

4.4.6 Data analytic plan

Reaction time and accuracy analysis were conducted through a mixed-design ANOVA (2×2×4), with Language ("Some Felicitous" and "Some Infelicitous") and Music (NO, MI, MS and Aug) as within-subjects factors and Group (M, NM) as between-subjects factor. In accuracy analysis, Mauchly's test indicated that the assumption of sphericity had been violated for both Language ($\chi 2(0) = .000$, $p =$ n.a.), and Music ($\chi 2(5) = .671$, $p = .009$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .36$). In the Language × Music interaction the assumption of sphericity is respected ($\chi 2(5) = .863$, $p = .337$), thus no further correction was needed. When analysing accuracy, two paired samples *t*-tests have been conducted for the interaction Language × Music and for the interaction Language × Group.

As for the reaction time analysis, 8.75% of total answers has been discarded because they were errors. As in Experiment 1, when underinformative sentences were interpreted pragmatically they were judged "false", thus, "true" answers in this condition were considered as errors. Another 2.75% of answers was discarded because they were given before 120msec, because they reflect anticipatory responses prior to proper stimulus processing, and after 4000ms, because answers after this time reflect distraction. For the remaining trials, I checked for outliers considering the RTs outside of the interval defined by the intra-subject average ±2.5 standard deviation, in order to minimize the impact of outliers on mean RT. Only another 0.04% of trials was discarded. I then calculated the average for each participant in each of the different conditions prior to the calculation of the grand average over all participants. Mauchly's test indicated that the assumption of sphericity had been violated for both Language ($\chi 2(0) = .000$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .91$); Music and the Language × Group interaction, on the contrary, assume the sphericity test (Music: $\chi 2(5) = .811$, $p = .201$; and the Language × Group interaction $\chi 2(5) = .806$, $p = .186$).

4.4.7 Results

To analyse both accuracy and reaction time in Experiment 2, I ran a mixed design ANOVA (2×2×4), with Language ("Some Felicitous", SF and "Some Infelicitous", SI) and Music (without music, NO; with music in tune in the background, MI; with dissonant target chord, MS; and with augmented target chord, Aug) as within-subjects factors and Group (Musicians, non-Musicians) as between-subjects factor. Hereafter, I will refer to the experimental conditions as SFNO for some felicitous without musical background, SFMI for some felicitous with music in tune, SFMS for some felicitous with dissonant target chord and SFA for some felicitous with augmented target chord, SINO for some infelicitous without music, SIMI for some infelicitous with music in tune in the background, SIMS for some infelicitous with dissonant target chord and SIA for some infelicitous with augmented target chord. I will also continue to refer to Groups as M for musicians and NM for non-musicians.

As for accuracy, a significant effect of Language was observed ($F(1,40)= 6.183$, $p = .017$) with a medium effect size (partial $\eta^2 = .134$). Post hoc comparisons with Bonferroni correction indicated that the mean error rate for SF (see Tables 5 and 6) was lower ($p = .017$) than the mean error rate for SI condition. This result suggests that SF is significantly more accurate than SI, thus indicating that the infelicitous condition is more difficult to process, confirming the results found in Experiment 1.

Table 5, *Descriptive plot of Post hoc analysis for Language*

Language	Mean	SD
SF	.040	.007
SI	.132	.036

Table 6, *Post hoc with Bonferroni correction for Language in accuracy*

Language	Language	SD	Sig.
FEL	INF	.037	.017
INF	FEL	.037	.017

A main effect of Music is also observed (F(2.43,97.1)= 5.63, p = .003), with a medium effect size (partial η^2 = .123). Bonferroni post hoc testing revealed that the condition NO (see Tables 7 and 8) was easier than the condition MI (p < .001); and that the condition Aug was easier than the condition MI (p = .034).

Table 7, *Descriptive plot of Post hoc analysis for Music*

Music	Mean	SD
NO	.065	.019
MI	.113	.019
MS	.087	.019
Aug	.079	.021

Table 8, *Post hoc with Bonferroni correction for Music in accuracy*

Music	Music	SD	Sig.
NO	MI	.010	.000
	MS	.012	.461
	A	.009	.747
MI	NO	.010	.000
	MS	.015	.548
	A	.012	.034
MS	NO	.012	.461
	MI	.015	.548
	A	.013	1.000
A	NO	.009	.747
	MI	.012	.034
	MS	.013	1.000

Other post hoc analyses did not reveal any statistical differences, as for the comparisons between the condition NO and the condition MS (p = .461), the condition NO and the condition Aug, (*p*= .747), suggesting that having no music, music with a dissonant chord or music with augmented target chord do not affect differently accuracy in the whole task. No significant differences have been found also between the condition MI and MS (*p*= .548), and the condition MS and Aug (*p*= 1.000). Thus, MI (*M*= .113) is the most difficult condition; it does not statistically differ from MS (*M*= .087) but it differs from Aug (*M*= .079) and from NO (*M*= .065). Conversely, MS do not statistically differ from MI or Aug.

Taken together, these results suggest that the presence of music, if it is in tune, makes the task harder, and this happens with respect to the conditions without musical background or with the augmented target chord. It is interesting to notice that no differences have been found between having no music and having a dissonant or an augmented target chord. Moreover, the difference between music in tune and music with dissonant target chord, as well as the difference between the condition with dissonant or the augmented target chord, is not significant. As a general conclusion, the ordering of the musical conditions is the following: NO is the easiest, followed by Aug and by MS, whereas the most difficult condition is MI (see Table 7).

Group is not significant ($F(1,40)= 3.678$, $p = .062$), with a medium effect size (partial $\eta^2 = .084$).

Table 9, *Descriptive plot for Group accuracy*

Group	Mean	SD
M	.051	.026
NM	.121	.025

Table 10, *Pair comparison between Groups in accuracy*

Group	Group	SD	Sig
M	NM	.036	.062
NM	M	.036	.062

The Language × Music interaction was significant ($F(3,120)= 9.654$, $p < .001$). The strength of this result, as indexed by the partial η^2, is large (.194). This indicates that the linguistic conditions are differently affected by the musical conditions.

4. Graph showing the interaction Language × Music.

In order to find out where Language significantly interacts with Music, I ran a series of paired samples *t*-tests for both groups together comparing SF and SI with all musical pairs: NO vs. MI; NO vs. MS; NO vs. Aug; MI vs. MS; MI vs. Aug; MS vs. Aug (see Tables 11 and 12).

In the infelicitous conditions, a significant difference is observed for SINO and SIMI ($t(41)= -6.331$, $p < .001$), SINO and SIMS ($t(41)= -2.194$, $p = .034$), SIMI and SIMS ($t(41)= 2.541$, $p = .015$); and SIMI and SIA, ($t(41)= 4.961$, $p < .001$). However, no differences are found for SINO and SIA ($t(41)= -.813$, $p = .421$) and for SIMS compared to SIA ($t(41)= 1.636$, $p = .109$).

Conversely, as for the interaction Language × Music in the felicitous contexts, no significant differences were observed. SFNO and SFMI were not statistically different ($t(41)= .829$, $p = .412$); this is true also for SFNO and SFMS ($t(41)= .198$, $p = .844$); for SFNO and SFA ($t(41)= -1$, $p = .323$); for SFMI and SFMS ($t(41)= -.404$, $p = .688$); for SFMI and SFA ($t(41)= -1.598$, $p = .118$); and for SFMS and SFA ($t(41)= -1.030$, $p = .309$). Thus, in the felicitous conditions music does not interfere with language processing.

Table 11, *Descriptive plot for paired samples t-tests (SF-SI in all musical conditions) in accuracy*

		Mean	N	SD
Pair 1	ACC SFNO	.04	42	.058
	ACC SFMI	.03	42	.067
Pair 2	ACC SFNO	.04	42	.058
	ACC SFMS	.04	42	.069
Pair 3	ACC SFNO	.04	42	.058
	ACC SFA	.05	42	.092
Pair 4	ACC SFMI	.03	42	.067
	ACC SFMS	.04	42	.069
Pair 5	ACC SFMI	.03	42	.067
	ACC SFA	.05	42	.092
Pair 6	ACC SFMS	.04	42	.069
	ACC SFA	.05	42	.092
Pair 7	ACC SINO	.10	42	.265
	ACC SIMI	.20	42	.249
Pair 8	ACC SINO	.10	42	.265
	ACC SIMS	.13988	42	.253335
Pair 9	ACC SINO	.10	42	.265
	ACC SIA	.11	42	.251
Pair 10	ACC SIMI	.20	42	.249
	ACC SIMS	.13988	42	.253335
Pair 11	ACC SIMI	.20	42	.249
	ACC SIA	.11	42	.251
Pair 12	ACC SIMS	.13988	42	.253335
	ACC SIA	.11	42	.251

Table 12, *Paired-samples t-tests for SF-SI in all musical conditions in accuracy*

		Mean	SD	t	df	Sig.
Pair 1	ACC SFNO - ACC SFMI	.009	.070	.829	41	.412
Pair 2	ACC SFNO - ACC SFMS	.003	.098	.198	41	.844
Pair 3	ACC SFNO - ACC SFA	-.015	.096	-1.000	41	.323
Pair 4	ACC SFMI - ACC SFMS	-.006	.095	-.404	41	.688

Pair 5	ACC SFMI - ACC SFA	-.024	.097	-1.598	41	.118
Pair 6	ACC SFMS - ACC SFA	-.018	.112	-1.030	41	.309
Pair 7	ACC SINO - ACC SIMI	-.104	.107	-6.331	41	.000
Pair 8	ACC SINO - ACC SIMS	-.044643	.131888	-2.194	41	.034
Pair 9	ACC SINO - ACC SIA	-.012	.095	-.813	41	.421
Pair 10	ACC SIMI - ACC SIMS	.059524	.151813	2.541	41	.015
Pair 11	ACC SIMI - ACC SIA	.092	.121	4.961	41	.000
Pair 12	ACC SIMS - ACC SIA	.032738	.129668	1.636	41	.109

What emerges from these results is that music affects the linguistic computation only in the infelicitous contexts. More particularly, the number of errors is significantly higher in the condition MI with respect to what is found in all other musical conditions (NO, MS and Aug). Another significant difference is observed in the comparison between the condition NO, being easier than the condition MS.

The interaction Language × Group was significant ($F(1,40) = 4.097$, $p = .050$), with a medium effect size as indexed by partial $\eta^2 = .093$. To analyse this interaction, I ran a paired-sample t-test on each group separately comparing SF to SI. In order to consider only the linguistic conditions, I obtained the score for the SF condition from the means of SFNO, SFMI, SFMS and SFA, and for the SI condition, the means of SINO, SIMI, SIMS and SIA. What emerges is that musicians do not statistically differ in the two linguistic conditions, (see Tables 13 and 14), $t(19) = -1.192$, $p = .248$), while non-musicians show a significant difference between the SF condition and the SI condition (see Tables 15 and 16), $t(21) = -2.410$, $p = .025$. What emerges is thus that non-musicians have a considerably worse performance in the pragmatically infelicitous condition, as found in Experiment 1. This difference was instead not found for musicians.

Table 13, *Descriptive plot for Language × Group (Musicians) in accuracy*

		Mean	N	SD
Pair 1	ACC FEL	.04	20	.049
	ACC INF	.0593750	20	.05815488

Table 14, *Paired-samples t-test Language × Group (Musicians) in accuracy*

		Mean	SD	t	df	sig.
Pair 1	ACC FEL - ACC INF	-.01718750	.06450326	-1.192	19	.248

Table 15, *Descriptive plot for Language × Group (Non-musicians) in accuracy*

		Mean	N	SD
Pair 1	ACC FEL	.04	22	.038
	ACC INF	.2045455	22	.31864892

Table 16, *Paired-samples t-test Language × Group (Non-musicians) in accuracy*

		Mean	SD	t	df	sig.
Pair 1	ACC FEL - ACC INF	-.16761364	.32626606	-2.410	21	.025

As for the other interactions, neither Music × Group is statistically significant (F(2.43,97.1)= 1.328, p = .271, partial η^2 = .032), nor Language × Music × Group, (F(3,120)= .640, p = .591, partial η^2 = .016).

Taken together, all these results indicate that subjects are more accurate in the felicitous condition than in the infelicitous one; this result is particularly strong for non-musicians, who showed a highly significant difference between the two linguistic conditions. As for Music, a significant effect has been observed for both groups, with the conditions with music in tune in the background featuring a higher error rate than the conditions without music or with augmented dissonant chord. As for the interaction between Language and Music, significant differences were found only in the infelicitous contexts; the musical condition with music in tune in the background is always the least accurate condition compared to all other musical conditions in the infelicitous context; another significant difference in the infelicitous context is that the condition with music with dissonant target chord turns out to be less accurate than the condition without any musical stimuli.

The analysis of reaction time of Experiment 2 has been run through a mixed design ANOVA with repeated measures. No main effects have been found for Group (F(1,36)= .420, p= .521, partial η^2 = .012) Language (F(1,36)= .387, p= .538, partial η^2 = .011) or Music (F(3,108)= 1.076, p= .358, partial η^2 = .029). Also, the interactions were not significant, considering Language × Music (F(3,108)= 1.058, p= .370, partial η^2 = .029); of Language × Group (F(1,36)= .527, p= .473, partial η^2 = .014); Music × Group interaction (F(3,108)= .906, p= .441, partial η^2 = .025); Language × Music × Group interaction (F(3,108)= 1.178, p= .322, partial η^2 = .032). Owing to the lack of significant main effects or interactions, no further post hoc tests were performed.

Summarizing, in Experiment 2 all significant data come from the accuracy analysis. As previously observed, the infelicitous condition is significantly less accurate than the felicitous condition, even though the significant Language × Group interaction reveals that musicians display a similar behavior in both conditions, while non-musicians show a higher error rate in the infelicitous condition. Regarding the musical stimuli, the presence of music in tune causes a significant increase in error rate compared to the conditions without musical background and with augmented target chord. Interestingly, the Language × Music interaction shows that in the infelicitous condition, the condition with music in tune in the background is the most difficult compared to all other musical conditions. I conclude thus that, regarding accuracy, an interaction between Language and Music is observed, with the conditions that involve music in tune featuring a significantly lower accuracy rate in comparison to all other musical conditions, starting from the absence of music, which emerges as the most accurate condition, followed by the *loudness manipulation* condition up to the condition with the out-of-key chord.

4.4.8 Discussion

The most interesting results emerging from Experiment 2 concern comprehension accuracy. I will therefore concentrate on these data.

Based on the literature review in chapter 3 on Experimental Pragmatics, and on the discussion of the results obtained in Experiment 1, I can conclude that accuracy analysis essentially confirms the predictions of the Relevance Theory approach. Pragmatically infelicitous sentences are generally more difficult to compute than the pragmatically felicitous sentences, although this difference is more marked for non-musicians.

Music has also a significant effect, since it is the case that participants have a different performance according to the musical background. More particularly, the ordering of complexity of the musical conditions is NO, Aug, MS and MI, with MI yielding the higher error rate. This is also observed in the interaction between Language and Music. Here, the only linguistic condition that is affected by music is the infelicitous *some* condition, whereas music does not affect the linguistic computation in the felicitous *some* condition. In this case as well, the ordering of the musical conditions is NO, Aug, MS and MI. I interpret these results as providing further support to the SSIRH, because whereas musical grammar interferes with linguistic processing, it does so only at a general cognitive level. The additive factors logic adopted by Patel (2003, 2008), Fedorenko *et al.* (2009) and Slevc *et al.* (2009) dictates in fact that the out-of-key condition should be the one that mostly interferes with the computation of pragmatically infelicitous sentences. This is essentially due to the hypothesis that increasing the degree of difficulty at the level of musical processing should make linguistic processing harder. However, in my study, it is the simultaneous presence of music (no matter if in tune or with the dissonant target chord) with language that interferes with the linguistic processing, with no further effects linked to the modulation of the musical conditions. These results can thus be interpreted as suggesting that musical processing and pragmatic processing only interfere in the sense of the additional cognitive cost triggered by the presence of a double cognitive task, whereas it is not the case that these two tasks involve the same neural network. I will discuss this more in detail in the general discussion section.

As for the differences between musicians and non-musicians, I found a marginal significant effect of language. While the group of musicians did not display a significantly different performance between the felicitous and the infelicitous condition, the group of non-musicians performed differently depending on whether they had to face the felicitous or the infelicitous *some* condition. Interestingly, the literature that explored the differences between musicians and non-musicians tested the behaviour of these two groups only on musical tasks and with respect to pitch processing in language, with an advantage for musicians with respect to non-musicians (see section 2.7). It can be the case that the results I obtained are an experimental artefact (i.e. maybe related to individual variables that I did not take into consideration), but it may also be the case that musical benefits have an impact that is not limited to pitch processing in language, but extends to other aspects of linguistic and cognitive processing, possibly in terms of executive function enhancement.

5. General Discussion and Conclusions

The effects of the computation of Scalar Implicatures based on the semantic and pragmatic readings of the quantifier *some* have been widely documented in psycholinguistics (see chapter 3). The present thesis intended to investigate these effects while assessing whether concomitant musical processing interferes with the cognitively demanding process of implicature computation, as analysed in Relevance Theory. In fact, this thesis provides further support to Relevance Theory by demonstrating, in both Experiment 1 and Experiment 2, that pragmatically felicitous sentences are easier to process than pragmatically infelicitous sentences. In both experiments, as I saw above, felicitous sentences give rise to a significantly higher accuracy rate than the pragmatically infelicitous sentences, although in Experiment 2 this effect was more marked for non-musicians.

The critical point of this work was to test the predictions of the SSIRH in a linguistic context involving a pragmatic computation. As already reported in chapter 2, Patel's hypothesis (2003, 2008, 2012) has been assessed in relation to both *syntactic* and to *semantic* processing in experimental contexts where musical processing was also involved. Works on the processing interference between linguistic syntax and musical syntax found a significant overlap resulting from the modulation of the difficulty of the musical task: making musical processing more difficult results in an increasing difficulty at the level of the syntactic computation in language, providing substantial evidence for the hypothesis that these two kinds of processing revolve around the same neural resources. On the other hand, tests on the interaction between semantic aspects of language and harmonic processing delivered divergent results. In fact, Fedorenko *et al.* (2009), Slevc *et al.* (2009), Hoch *et al.* (2011) did found an overlap in the syntactic processing in language and music, but no overlap in the simultaneous processing of linguistic semantics and music (for semantic processing see also Bonnel *et al.*, 2001, and Besson *et al.*, 1998). However, the work of Poulin-Charronat *et al.* (2005) did actually found an interaction between semantic and harmonic relatedness. Given these conflicting results, and their conceptual import to the SSIRH, a natural question that arises is whether the kind of pragmatic processing typical to (scalar) implicature computation significantly interferes with musical processing. Though implicature computations certainly make reference to linguistic knowledge, the kind of processual resources that it involves are of a more general cognitive nature, and they are likely to be external to the processes of online integration of specifically syntactic representation that are shared by language and music according to the SSIRH. It follows that the main focus of this work is on testing the predictions of the SSIRH with respect to the specific sort of meaning represented by a specific class of pragmatic computations. What I found is arguably quite interesting from the perspective of the SSIRH. First of all, according to our results, music interferes with linguistic processing, but it does so only in the most difficult linguistic condition, i.e. the condition in which calculating the pragmatics meaning of *some* gives rise to a contextually infelicitous result. Importantly, this effect was found using two distinct tasks, a statement evaluation task (Experiment 1) and a sentence-picture verification task (Experiment 2). In fact, in both experiments felicitous sentences did not show any significant difference with respect to the presence/absence of music. Conversely, the pragmatically infelicitous condition was in both cases clearly affected by the presence of music, giving rise to different behavioral results depending on how the presence of music is modulated in the experiment. More precisely, in the absence of musical background both groups (musicians and non-musicians) perform better, while their performance starts to decrease in the presence of music in the loudness manipulation condition. Interestingly, the musical conditions that mostly influence the subjects' accuracy rate, progressively leading to a worse performance, are the conditions with the out-of-key chord and with the in-tune musical background. What this suggests is that the interference between language and music is only found in the linguistic condition where the cognitive load is higher, according to the Relevance Theory analysis of implicature computation. In a sense, when music is present, the subject is evidently confronted with the task of processing two distinct classes of stimuli, and this is arguably a more difficult task than processing only one class of stimuli. This is exactly what my results reveal: the condition without music is simpler than the conditions involving the concomitant processing of musical stimuli. Not surprisingly, the cognitive cost of this double processing task only emerges when the linguistic load is independently heavy, i.e. in the infelicitous some condition. At the same time, these results raise the question how the interference between language and music is exactly modulated.

In fact, what I found in Experiment 1 is a general interference between language and music, which I wanted to better investigate by adding two more musical conditions (Experiment 2), corresponding to the loudness manipulation and the condition with the out-of-key chord. Quite significantly from the perspective of the SSIRH, what I found here is that the conditions with music in tune in the background and with the out-of-key chord do not significantly differ. On the contrary, this condition manifests a higher error rates if compared to the loudness manipulation condition and to the condition without musical background. The additive factors logic on which Patel (2003, 2008), Fedorenko *et al.* (2009) and Slevc *et al.* (2009) crucially rely explicitly predicts that increasing the difficulty of the musical condition should make linguistic processing significantly harder. This is because according to the SSIRH, music and language do not presuppose the same kind of knowledge and the same sort of cognitive representations: rather, language and music make use of the same neural resources in the process of online access and integration of these representations. Increasing the cost of musical processing should then immediately result in higher processing difficulties in the analysis of the linguistic stimuli. Crucially, this is not what I found. Given my results, modulating the degree of musical difficulty does not make the difficult linguistic condition harder. On the contrary, there is no significant difference among the conditions with music in the background, and the condition with the music in-tune (the simpler musical condition) affects in fact the pragmatic computation more than the condition with the music out-of-tune. What this suggests is that the music interferes with the pragmatic computation only at a general cognitive level. Pragmatic processing and musical processing rely on two distinct sets of neural resources and only interferes in the sense in which a subject who faces a double cognitive task is more burdened, in terms of processing resources, than a subject facing only one cognitive task. What I do not find is the effect that was typically predicted by the SSIRH: increasing the difficulty at the level of musical processing (the effect linked to the presence of the out-of-tune chord) should immediately results in higher error rates and/or higher reaction times at the level of the pragmatic computation. My results suggest that this is not what happens. In fact, I found that the acoustic loudness condition is the in-between condition: it affects the pragmatic computation more than the condition without music in the background but less than the two conditions with music in the background. A possibility is that the subjects discarded the music in the loudness condition as a sort of background noise, concentrating then more easily on the task of processing the linguistic stimuli. Of course, further studies are needed to confirm the correctness of this insight. Similarly, the interpretation I have proposed of my results is crucially based on the addictive factors logic adopted by Patel (2003, 2008), Fedorenko *et al.* (2009) and Slevc *et al.* (2009). All in all, however, I think that my results provide a non-trivial confirmation of the SSIRH: whereas syntactic processing is actually the same in language and music, in the sense that accessing and integrating the relevant representations makes use of the very same neural resources, musical processing and pragmatic processing make arguably use of distinct neural networks, and an interference between them manifests itself only at a more general cognitive level, in the sense that double processing tasks are more costly than a single processing task.

The last point to be discussed concerns the difference between musicians and non-musicians. The literature explored in section 2.7 reports the benefits of musical training that are related to basic auditory properties and to the morphological brain differences between musicians and non-musicians, among others. However, we know that not all the studies that explored the skills of musicians compared to those of non-musicians through the interference paradigm show a significant difference. Loui and Wessel (2007) reported, in fact, that the behaviour of the two groups differs in relation to the task, depending on whether it is explicit or implicit. In my study, both in Experiment 1 and in Experiment 2, the musical task is implicit, thus I did not expect any difference between the groups, based on previous results discussed in the literature. My predictions have been essentially confirmed. However, I found that there is a marginal effect for group in the linguistic condition (in Experiment 1 for RTs and in Experiment 2 for accuracy). The group of musicians did not show any difference in the computation of scalar implicatures in both Experiment 1 (as for RTs) and Experiment 2 (for accuracy), while the group of non-musicians showed slower response times in Experiment 1 in the pragmatically infelicitous condition compared to the pragmatically felicitous condition, and a higher error rate in Experiment 2 in the pragmatically infelicitous condition compared to the pragmatically felicitous condition. As argued above, it is possible that this is an experimental artefact related to individual variables that I did not consider or to the relatively small sample of subjects; notice moreover that the difference between musicians and non-musicians was only marginally significant. Alternatively, it may be that the cognitive benefits of musical training extend to pragmatic processing of linguistic stimuli, probably via executive function enhancement. I leave this to future studies.

In summary, the contributions of the present thesis are the following. First of all, my results confirm the predictions of the Relevance Theory approach concerning the cognitive cost of implicature computation: the infelicitous *some* condition emerged as significantly more difficult than the felicitous *some* condition. Second, concerning the interaction between music and language, I obtained an interesting set of results, whose interpretation suggests that syntactic processing in music and the kind of pragmatic meaning linked to (scalar) implicature computation interfere only at a general level, supporting the view that musical processing revolves around a distinct neural network with respect to pragmatic processing in language. This provides further support for the SSIRH, not only regarding the hypothesis that the neural overlap between language and music is limited to syntax, but also with respect to the hypothesis that this overlap is limited to online integration of the processed stimuli and does not extend to knowledge representation. In fact, what I found is only relevant for processing: the additive factors logic dictates that increasing the difficulty of the musical stimuli should increase the interference with the linguistic computation. Whereas this is exactly what happens when the cognitive cost of linguistic processing is essentially discharged into syntax, my results reveal that this is not the case when the cognitive cost of linguistic processing is discharged into the essentially non-syntactic mechanisms involved in implicature computation. Last but not least, this work demonstrates that it can be of interest testing musicians and non-musicians on purely linguistic tasks not related to pitch processing.

Appendix A: STIMULI EXPERIMENT 1 – Statement Evaluation Task

Linguistic stimuli

Felicitous sentences with the quantifier "some"

1. La signora Elena Zacchi dice che alcuni quadrupedi sono dei cavalli.
   Ms. Elena Zacchi says that some quadrupeds are horses.
2. La signora Laura Rado dice che alcune uova sono di quaglia.
   Ms. Laura Rado says that some eggs are from quail.
3. Il signor Carlo Bacci dice che alcuni cani sono dei dalmata.
   Mr. Carlo Bacci says that some dogs are Dalmatian.
4. La signora Emily Menti dice che alcune armi sono da taglio.
   Ms. Emily Menti says that some weapons are melee weapons.
5. Il signor Mirko Felzi dice che alcuni pesci sono dei salmoni.
   Mr. Mirko Felzi says that some fishes are salmons.
6. Il signor Loris Machi dice che alcune pietre sono di zaffiro.
   Mr. Loris Machi says that some stones are (made) of sapphire.
7. Il signor Paolo Maddi dice che alcune piante sono delle querce.
   Mr. Paolo Maddi says that some trees are oaks.
8. Il signor Piero Babbo dice che alcuni uccelli sono dei passeri.
   Mr. Piero Babbo says that some birds are sparrows.
9. Il signor Denis Ruffi dice che alcune scarpe sono da ginnastica.
   Mr. Denis Ruffi says that some shoes are sneakers.
10. Il signor Bruno Fabri dice che alcuni denti sono dei molari.
    Mr. Bruno Fabri says that some teeth are molars.

Infelicitous sentences with the quantifier "some"

11. La signora Giada Vinco dice che alcuni incisivi sono dei denti.
    Ms. Giada Vinco says that some incisors are teeth.
12. La signora Agata Tacci dice che alcune mele sono dei frutti.
    Ms. Agata Tacci says that some apples are fruits.

13. Il signor Luigi Tagli dice che alcuni squali sono dei pesci.
    Mr. Luigi Tagli says that some sharks are fishes.
14. Il signor Ivano Taibi dice che alcune formiche sono degli insetti.
    Mr. Ivano Taibi says that some ants are insects.
15. Il signor Lucio Penna dice che alcuni gatti sono dei felini.
    Mr. Lucio Penna says that some cats are felines.
16. Il signor Abele Verdi dice che alcune meduse sono dei molluschi.
    Mr. Abele Verdi says that some jellyfishes are molluscs.
17. La signora Ivana Rossi dice che alcuni canguri sono dei marsupiali.
    Ms. Ivana Rossi says that some kangaroos are marsupials.
18. La signora Lucia Bianchi dice che alcune rane sono dei rettili.
    Ms. Lucia Bianchi says that some frogs are reptiles.
19. Il signor Diego Vella dice che alcuni orsi sono dei mammiferi.
    Mr. Diego Vella says that some bears are mammals.
20. La signora Sofia Palma dice che alcune margherite sono dei fiori.
    Ms. Sofia Palma says that some daisies are flowers.

Fillers:

Fillers with the quantifier "all" in true context.

21. La signora Noemi Pasci dice che tutti i molluschi sono invertebrati.
    Ms. Noemi Pasci says that all the molluscs are invertebrates.
22. La signora Giulia Russo dice che tutte le lucertole sono rettili.
    Ms. Giulia Russo says that all the lizards are reptiles.
23. La signora Greta Rosso dice che tutti i topi sono roditori.
    Ms. Greta Rosso says that all the mice are rodents.
24. La signora Adele Bianco dice che tutte le rondini sono uccelli.
    Ms. Adele Bianco says that all the swallows are birds.
25. La signora Alice Ferri dice che tutti i leoni sono carnivori.
    Ms. Alice Ferri says that all the lions are carnivorous.
26. La signora Sonia Magni dice che tutte le mucche sono femmine.
    Ms. Sonia Magni says that all the cows are females.

27. La signora Anita Fanci dice che tutti i ciclamini sono fiori.
    Ms. Anita Fanci says that all the cyclamens are flowers.
28. La signora Erika Greco dice che tutte le coccinelle sono insetti.
    Ms. Erika Greco says that all the ladybugs are insects.
29. Il signor Adamo Gallo dice che tutti i maiali sono onnivori.
    Mr. Adamo Gallo says that all the pigs are omnivorous.
30. Il signor Adone Conti dice che tutte le gazzelle sono mammiferi.
    Mr. Adone Conti says that all the gazelles are mammals.

Fillers with the quantifier "all" in false context.

31. Il signor Alfio Costa dice che tutti gli alberi sono betulle.
    Mr. Alfio Costa says that all the trees are birches.
32. La signora Dania Bianchi dice che tutte le piante sono sempreverdi.
    Ms. Dania Bianchi says that all the trees are evergreen.
33. Il signor Efrem Rizzo dice che tutti i fiori sono rossi.
    Mr. Efrem Rizzo says that all the flowers are red.
34. Il signor Ennio Ruggi dice che tutte le gravidanze sono gemellari.
    Mr. Ennio Ruggi says that all the pregnancies are twin.
35. Il signor Fabio Rossi dice che tutti i cavalli sono bianchi.
    Mr. Fabio Rossi says that all the horses are white.
36. Il signor Guido Galli dice tutte le erbe sono officinali.
    Mr. Guido Galli says that all the grasses are medicinal herbs.
37. La signora Ambra Longo dice che tutti i vertebrati sono ghepardi.
    Ms. Ambra Longo says that all the vertebrates are cheetahs.
38. La signora Amina Serra dice che tutte le piante sono velenose.
    Ms. Amina Serra says that all the plants are poisonous.
39. Il signor Italo Villa dice che tutti i crostacei sono granchi.
    Mr. Italo Villa says that all the crustaceans are crabs.
40. Il signor Leone Russi dice che tutte le rose sono bianche.
    Mr. Leone Russi says that all the roses are white.

Fillers without quantifier in true context.

41. Il signor Muzio Pasco dice che la luna è un satellite.
    Mr. Muzio Pasco says that the moon is a satellite.
42. Il signor Nereo Gatti dice che il dado ha sei facce.
    Mr. Nereo Gatti says that the dice has six faces.
43. Il signor Omero Sanna dice che il sole sorge ad est.
    Mr. Omero Sanna says that the sun rises on the east.
44. Il signor Orfeo Grasso dice che l'invidia è un peccato capitale.
    Mr. Orfeo Grasso says that envy is a capital sin.
45. Il signor Oscar Monti dice che il liquore è un alcolico.
    Mr. Oscar Monti says that the liqueur is an alcoholic drink.
46. Il signor Rocco Testa dice che Roma è la città eterna.
    Mr. Rocco Testa says that Rome is the eternal city.
47. Il signor Tobia Piras dice che gli attori recitano nei film.
    Mr. Tobia Piras says that all the actors perform on movies.
48. Il signor Vasco Adami dice che Luca è nome di persona.
    Mr. Vasco Adami says that Luca is name of person.
49. La signora Clara Pavan dice che le pesche crescono sugli alberi.
    Ms. Clara Pavan says that all the peaches grow on trees.
50. La signora Dafne Furla dice che il salame è un insaccato.
    Ms. Dafne Furla says that the salami is a sausage.
51. La signora Delia Basso dice che il cibo indiano è speziato.
    Ms. Delia Basso says that Indian food is spicy.
52. La signora Doris Fabri dice che la barba è tipicamente maschile.
    Ms. Doris Fabri says that the beard is typically masculine.
53. Il signor Elvio Costa dice che Londra è una grande metropoli.
    Mr. Elvio Costa says that London is a big metropolis.
54. La signora Flora Baggi dice che le patate sono dei tuberi.
    Ms. Flora Baggi says that the potatoes are tubers.
55. Il signor Ezio Frigo dice che Mozart è un compositore famoso.
    Mr. Ezio Frigo says that Mozart is a famous composer.
56. La signora Gemma Rigon dice che un secolo dura cento anni.

Ms. Gemma Rigon says that a century lasts hundred years.

57. Il signor Enzo Pozza dice che Venezia è capoluogo del Veneto.

    Mr. Enzo Pozza says that Venice is the county seat in Veneto.

58. La signora Gioia Bizzo dice che gli elefanti hanno la proboscide.

    Ms. Gioia Bizzo says that elephants have trunks.

59. La signora Irene Scarpa dice che le biciclette hanno le ruote.

    Ms. Irene Scarpa says that bicycles have wheels.

60. La signora Jenny Penzo dice che lo spumante è un vino.

    Ms. Jenny Penzo says that sparkling wine is a wine.

Fillers without quantifier in false context.

61. La signora Irina Tozzo dice che il sole è un pianeta.

    Ms. Irina Tozzo says that the sun is a planet.

62. La signora Luana Bosco dice che il cane è un roditore.

    Ms. Luana Bosco says that the dog is a rodent.

63. La signora Nadia Niero dice che la Cina è un continente.

    Ms. Nadia Niero says that China is a continent.

64. La signora Tecla Carra dice che il sangue è color verde.

    Ms. Tecla Carra says that blood is green.

65. La signora Vanda Zanon dice che i segni zodiacali sono venti.

    Ms. Vanda Zanon says that the zodiac signs are twenty.

66. La signora Monia Zanin dice che i sassi sono pietre morbide.

    Ms. Monia Zanin says that rocks are soft stones.

67. La signora Zaira Basso dice che i messicani parlano il francese.

    Ms. Zaira Basso says that the Mexicans speak French.

68. La signora Luisa Ferri dice che il cinque segue il tre.

    Ms. Luisa Ferri says that five follows the three.

69. Il signor Gianni Grandi dice che la settimana ha dieci giorni.

    Mr. Gianni Grandi says that the week has ten days.

70. Il signor Mario Tonon dice che Berlino è una città italiana.

    Mr. Mario Tonon says that Berlin is an Italian city.

71. La signora Maria Nanni dice che il cucito è uno sport.

Ms. Maria Nanni says that needlework is a sport.

72. La signora Lucia Sarti dice che il criceto è un bovino.

    Ms. Lucia Sarti says that the hamster is a bovine.

73. La signora Marta Naldi dice che il Tamigi è un lago.

    Ms. Marta Naldi says that the Tamigi is a lake.

74. Il signor Marco Burti dice che la lava vulcanica è fredda.

    Mr. Marco Burti says that the volcanic lave is cold.

75. La signora Tosca Moser dice che il tofu è un salume.

    Ms. Tosca Moser says that tofu is a salami.

76. La signora Gianna Cocco dice che Atene è in Nuova Zelanda.

    Ms. Gianna Cocco says that Athens is in New Zealand.

77. Il signor Berto Pozzi dice che i Re Magi erano cinque.

    Mr. Berto Pozzi says that the Biblical Magi were five.

78. La signora Daria Salvi dice che Manzoni scrisse la Divina Commedia.

    Ms. Daria Salvi says that Manzoni wrote the Divine Comedy.

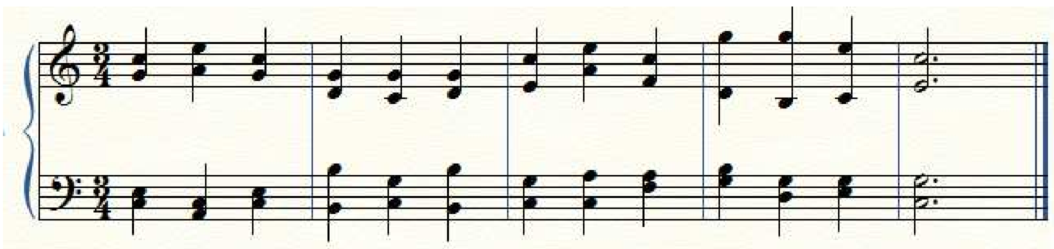
79. Il signor Diego Berti dice che i serpenti hanno le zampe.

    Mr. Diego Berti says that snakes have legs.

Musical Stimuli

Numbers are related to the linguistic sentences above.

1.



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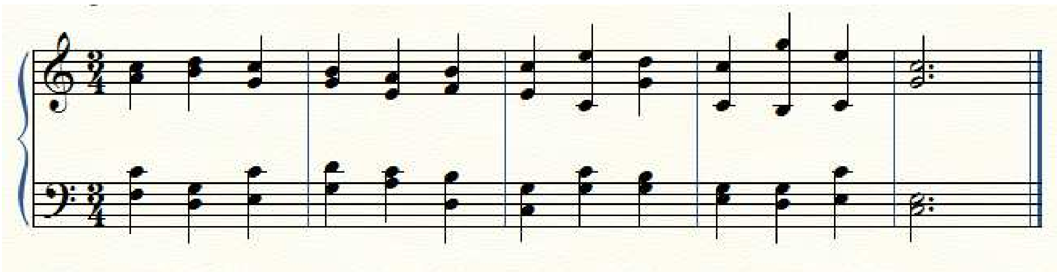

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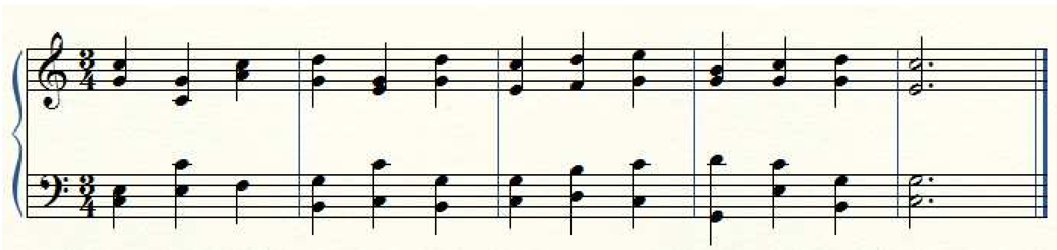

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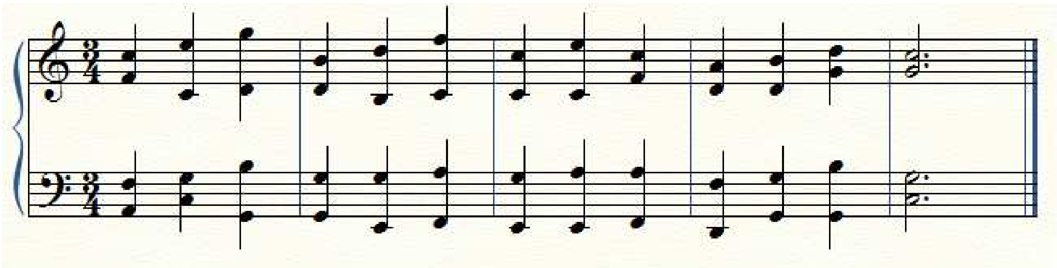

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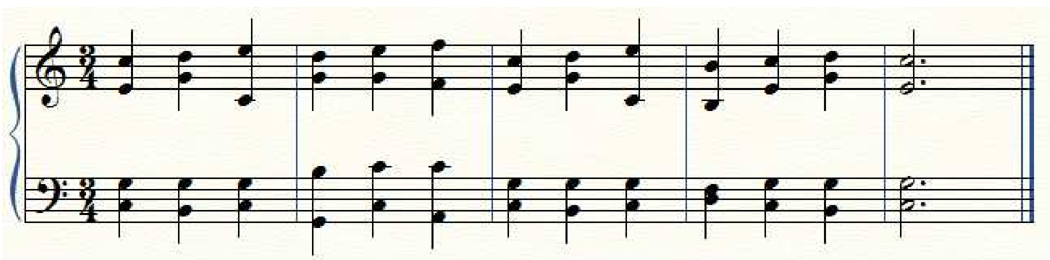

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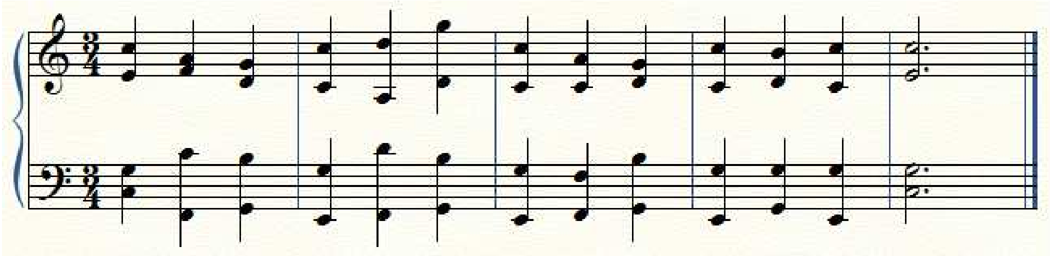

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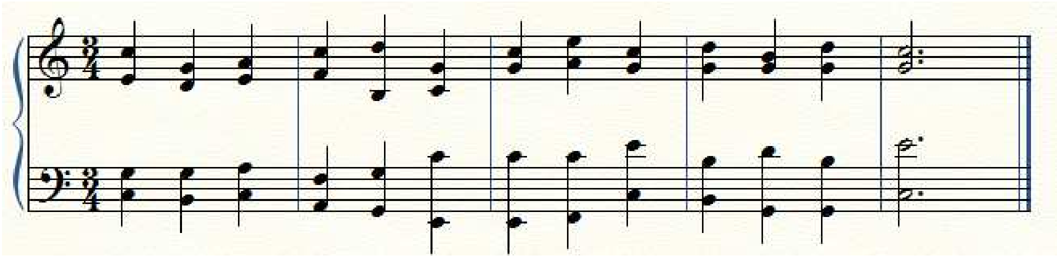

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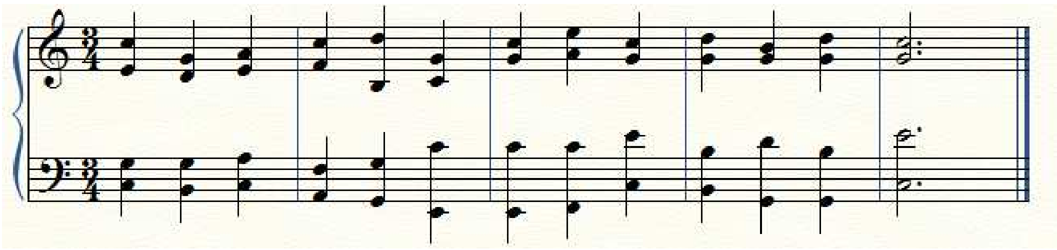

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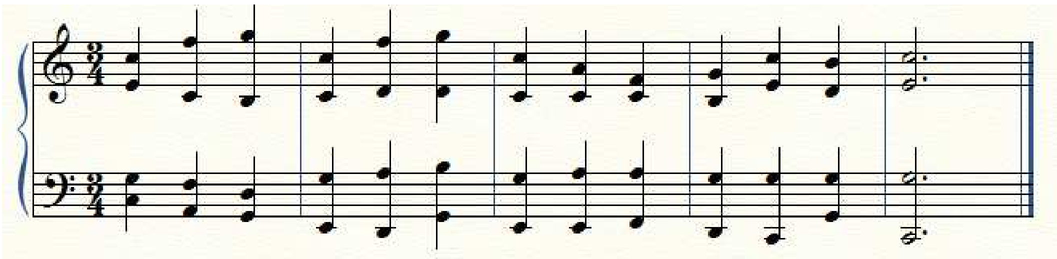

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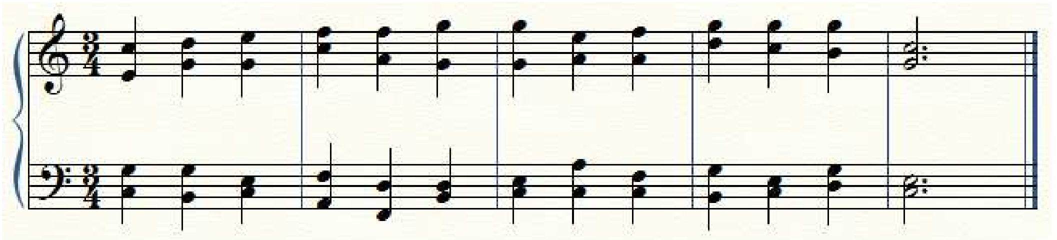

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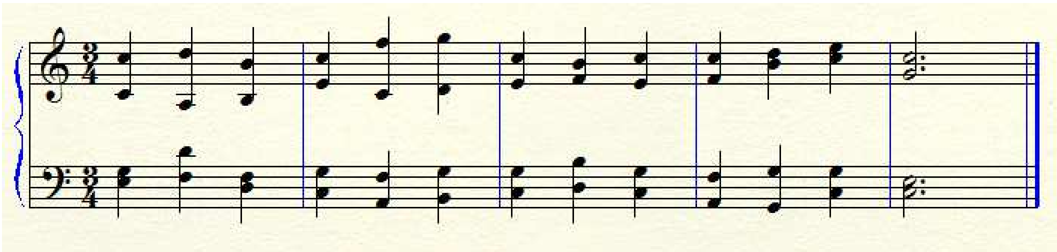

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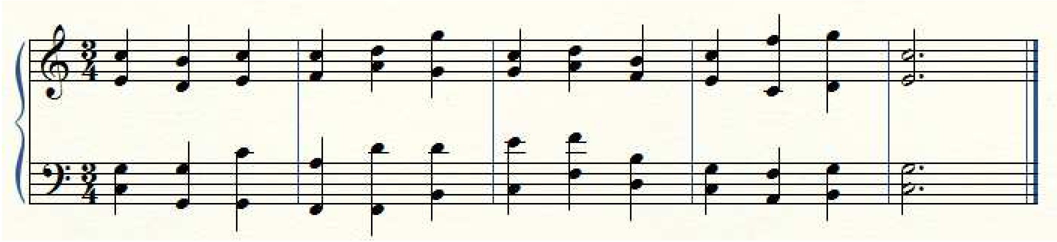

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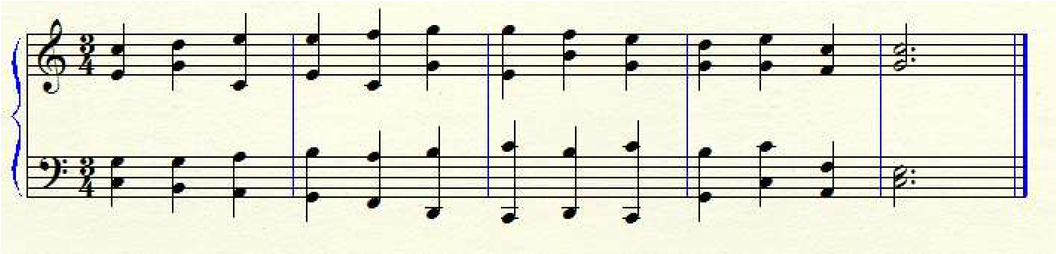

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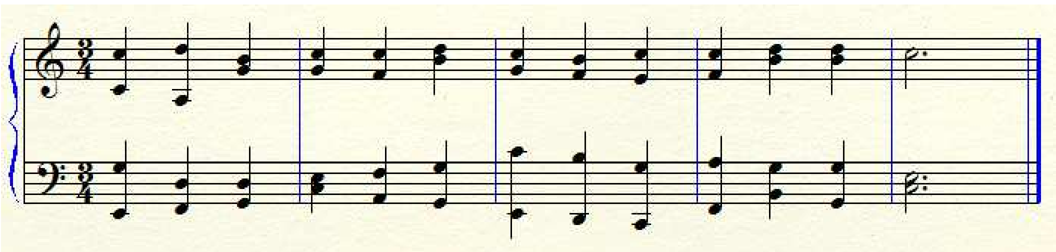

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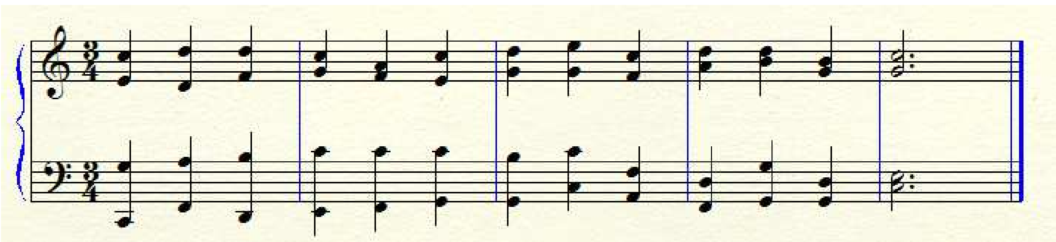

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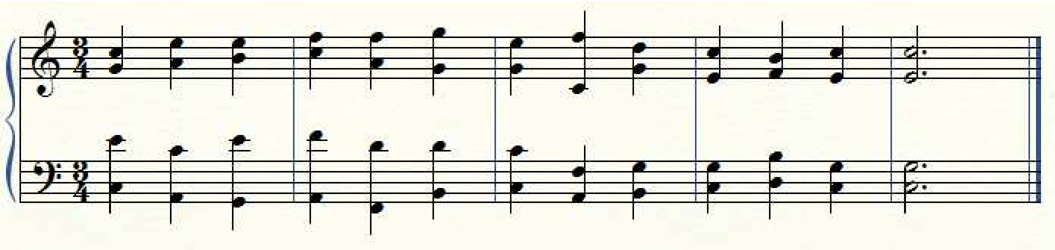

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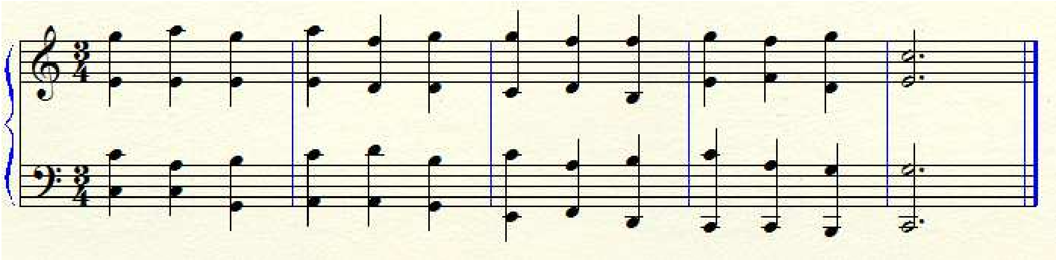

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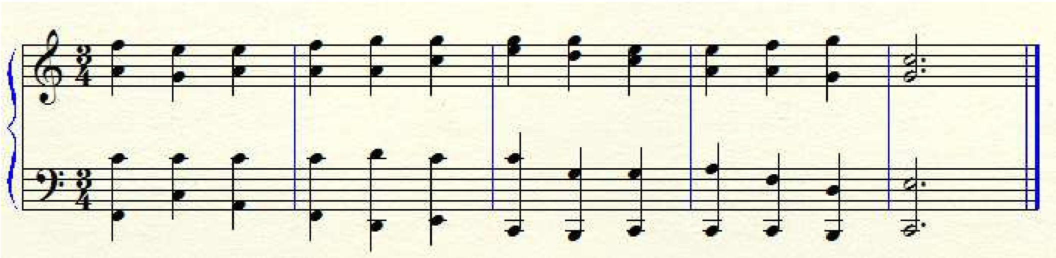

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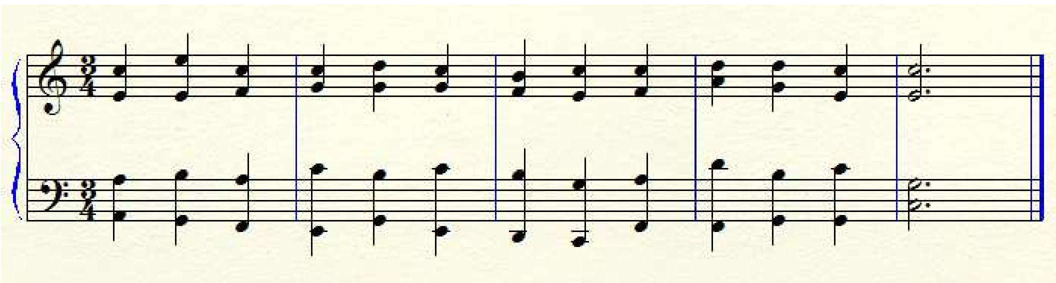


69.

70.

APPENDIX B: STIMULI EXPERIMENT 2 – Sentence Picture Verification Task

Linguistic stimuli

We remind that linguistic stimuli in Experiment 2 were presented word by word concomitant to the musical chord or a chunk of words concomitantly to the musical chord. The linguistic subdivisions here are indicated by an hyphen.

Felicitous sentences with the quantifier "some"

1. La vecchietta – in blu – ha – alcuni – dei – gatti – che vedi
   The old lady – in blue – has – some – of the cats – that you see
2. Il – cesto – contiene – alcuni – dei – gattini – che vedi
   The – basket – contains – some – of the – cats – that you see
3. La ragazza – castana – ha – alcune – delle – sciarpe – che vedi
   The girl – with brown hair – has – some – of the – scarves – that you see
4. La bambina – bionda – ha – alcuni – dei – fiori – che vedi
   The little girl – with blond hair – has – some – of the – flowers – that you see
5. Il bambino – castano – ha – alcune – delle – palle – che vedi
   The little boy – with brown hair – has – some – of the – balls – that you see
6. Il gatto – di profilo – ha – alcune – delle – zucche – che vedi
   The cat – in profile – has – some – of the – pumpkins – that you see
7. La – bambina – ha – alcune – delle – decorazioni – che vedi
   The – little girl – has – some – of the – decorations – that you see
8. Il bambino – castano – ha – alcuni – dei – cani – che vedi
   The little boy – with brown hair – has – some – of the – dogs – that you see
9. La bambina – in rosa – gioca con – alcune – delle – macchinine – che vedi
   The little girl – in pink – plays with – some – of the – small cars – that you see
10. Il – coniglio – porta – alcune – delle – carote – che vedi
    The – bunny – carries – some – of the – carrots – that you see
11. La – bambina – ha – alcuni – degli – orsetti – che vedi

The – little girl – has – some – of the – teddy bears – that you see

12. Il – pinguino – ha – alcune – delle – palle – che vedi

    The – penguin – has – some – of the – balls – that you see

13. Il – cagnolino – ha – alcuni – degli – ossi – che vedi

    The – little dog – has – some – of the – bones – that you see

14. Il – gatto – nero – ha – alcuni – dei – pesci – che vedi

    The – black – cat – has – some – of the – fishes – that you see

15. La – bambina – ha – alcune – delle – bambole – che vedi

    The – little girl – has – some – of the – dolls – that you see

16. Il – nonno – ha – alcuni – dei – libri – che vedi

    The – old man – has – some – of the – books – that you see

17. La – vecchietta – ha – alcune – delle – lettere – che vedi

    The – old lady – has – some – of the – letters – that you see

18. Il – cagnolino – ha – alcuni – dei – polli arrosto – che vedi

    The – little dog – has – some – of the – roasted chicken – that you see

19. La – scimmia – ha – alcune – delle – ghiande – che vedi

    The – monkey – has – some – of the – acorns – that you see

20. La – bambina – ha – alcuni – dei – pesci – che vedi

    The – little girl – has – some – of the – fishes – that you see

21. Il – pinguino – ha – alcune – delle – palle – che vedi

    The – penguin – has – some – of the – balls – that you see

22. Il coniglio – in rosso – ha – alcune – delle – lattughe – che vedi

    The bunny – in red – has – some – of the – lettuces – that you see

23. La – scimmia – ha – alcune – delle – banane – che vedi

    The – monkey – has – some – of the – bananas – that you see

24. Dietro – al nonno – ci sono – alcune – delle – sveglie – che vedi

    Behind – grandfather – there are – some – of the – alarm clocks – that you see

25. Babbo – Natale – ha – alcuni – dei – doni – che vedi

    Santa – Claus – has – some – of the – gifts – that you see

26. Il – ragazzo – ha – alcuni – dei – quaderni – che vedi

    The – boy – has – some – of the – copybooks – that you see

27. Il – cagnolino – ha – alcuni – degli – ossi – che vedi

The – little dog – has – some – of the – bones – that you see

28. Il – bambino – ha – alcuni – dei – secchielli – che vedi

    The – little boy – has – some – of the – small buckets – that you see

29. Il – ragazzo – ha – alcuni – dei – vasi – che vedi

    The – boy – has – some – of the – vases – that you see

30. L'orso – bruno – ha – alcuni – dei – vasetti – che vedi

    The brown – bear – has – some – of the – small jars – that you see

31. La bambina – in rosa – ha – alcune – delle – stelle – che vedi

    The little girl – in pink – has – some – of the – stars – that you see

32. Il bambino – in verde – ha – alcuni – dei – secchi – che vedi

    The little boy – in green – has – some – of the – baskets – that you see

Infelicitous sentences with the quantifier "some"

33. Il – bambino – ha – alcune – delle mele – raccolte – che vedi

    The – little boy – has – some – of the harvested – apples – that you see

34. La – bambina – ha – alcune – delle – stelle – che vedi

    The – little girl – has – some – of the – stars – that you see

35. La – nonna – ha – alcuni – dei – gattini – che vedi

    The – old lady – has – some – of the – kittens – that you see

36. La ragazza – in blu – ha – alcune – delle – sciarpe – che vedi

    The girl – in blu – has – some – of the – scarves – that you see

37. Il – cagnolino – ha – alcuni – degli – ossi – che vedi

    The – little dog – has – some – of the – bones – that you see

38. L'orso – grigio – ha – alcuni – dei – calamari – che vedi

    The gray – bear – has – some – of the – calamari – that you see

39. Il – bambino – ha – alcune – delle – palette – che vedi

    The – little boy – has – some – of the – small shovels – that you see

40. Il – bambino – ha – alcune – delle – sveglie – che vedi

    The – little boy – has – some – of the – alarm clocks – that you see

41. La – ragazza – porta – alcuni – dei – libri – che vedi

    The – girl – carries – some – of the – books – that you see

42. La – scimmia – ha – alcune – delle – ghiande – che vedi

The – monkey – has – some – of the – acorns – that you see

43. Lo gnomo – in blu – ha – alcuni – dei – funghi – che vedi

    The gnome – in blue – has – some – of the – mushrooms – that you see

44. Il cane – sta – cacciando – alcuni – dei – topini – che vedi

    The dog – is – hunting – some – of the – mice – that you see

45. Il – bambino – ha – alcuni – dei – regali – che vedi

    The – little boy – has – some – of the – presents – that you see

46. Il – pappagallo – ha – alcune – delle – banane – che vedi

    The – parrot – has – some – of the – bananas – that you see

47. Il – bambino – ha – alcuni – dei – pasticcini – che vedi

    The – little boy – has – some – of the – pastries – that you see

48. La ragazza – in rosa – ha – alcune – delle – sciarpe – che vedi

    The girl – in pink – has – some – of the – scarves – that you see

49. L'orso – grigio – ha – alcuni – dei – vasetti – che vedi

    The gray – bear – has – some – of the – small jars – that you see

50. Il – signore – ha – alcuni – dei – cani – che vedi

    The – man – has – some – of the – dogs – that you see

51. L'elfo – natalizio – ha – alcuni – degli – orsacchiotti – che vedi

    The Christmas – elf – has – some – of the – teddy bears – that you see

52. La – ragazza – ha – alcuni – dei – gatti – che vedi

    The – girl – has – some – of the – cats – that you see

53. Il – ragazzo – ha – alcuni – dei – pappagalli – che vedi

    The – boy – has – some – of the – parrots – that you see

54. Il – pinguino – ha – alcuni – dei – berretti – che vedi

    The – penguin – has – some – of the – caps – that you see

55. Il – coniglio – ha – alcune – delle – carote – che vedi

    The – bunny – has – some – of the – carrots – that you see

56. Il – cuoco – ha – alcuni – dei – cucchiai – che vedi

    The – chef – has – some – of the – spoons – that you see

57. Il – ragazzo – ha – alcuni – dei – frutti – che vedi

    The – boy – has – some – of the – fruits – that you see

58. Il – topo – ha – alcuni – dei – formaggini – che vedi

    The – mouse – has – some – of the – cheeses – that you see

59. Lo – scoiattolo – ha – alcune – delle – mele – che vedi
    The squirrel – has – some – of the – apples – that you see
60. La – ragazza – ha – alcuni – degli – zaini – che vedi
    The – girl – has – some – of the – rucksacks – that you see
61. Il – bambino – ha – alcune – delle – caramelle – che vedi
    The – little boy – has – some – of the – candies – that you see
62. Il – fruttivendolo – ha – alcune – delle – lattughe – che vedi
    The – greengrocer – has – some – of the – lattuces – that you see
63. L'orso bruno – ha – preso – alcuni – dei – vasetti – che vedi
    The brown bear – has – brought – some – of the – little jars – that you see
64. Il – ragazzo – ha – alcuni – dei – birilli – che vedi
    The – boy – has – some – of the – bowling pins – that you see

Fillers:

Fillers with the quantifier "all" in true context.

65. Il – bambino – ha – tutti – i – palloni – che vedi
    The – little boy – has – all – the – balls – that you see
66. La – bambina – ha – tutte – le – matite – che vedi
    The – little girl – has – all – the – pencils – that you see
67. Il – delfino – ha – tutti – i – birilli – che vedi
    The – dolphin – has – all – the – bowling pins – that you see
68. Il – pinguino – ha – tutti – i – calamari – che vedi
    The – penguin – has – all – the – calamari – that you see
69. Il – bambino – ha – tutti – i – disegni – che vedi
    The – little boy – has – all – the – drawings – that you see
70. La – ragazza – ha – tutti – i – pasticcini – che vedi
    The – girl – has – all – the – pastries – that you see
71. Il – cane – ha – tutti – i – polli arrosto – che vedi
    The – dog – has – all – the – roasted chicken – that you see
72. Il – cane grande – ha – tutti – gli – ossi – che vedi
    The – big dog – has – all – the – bones – that you see

73. La – ragazza – ha – tutti – i – cani – che vedi
    The – girl – has – all – the – dogs – that you see
74. La – vecchietta – ha – tutti – i – pasticcini – che vedi
    The – old lady – has – all – the – pastries – that you see
75. Il – gatto grigio – ha – tutte – le – palline – che vedi
    The – gray cat – has – all – the – little balls – that you see
76. La – bambina – ha – tutte – le – bambole – che vedi
    The – little girl – has – all – the – dolls – that you see
77. L'orso – bruno – ha – tutti – i – birilli – che vedi
    The brown – bear – has – all – the – bowling pins – that you see
78. Il – bambino – ha – tutte – le – bambole – che vedi
    The – little boy – has – all – the – dolls – that you see
79. Il – bambino – ha – tutti – i – pasticcini – che vedi
    The – little boy – has – all – the – pastries – that you see
80. La – tartaruga – ha – tutte – le – carote – che vedi
    The – tortoise – has – all – the – carrots – that you see
81. Nel – recinto – ci sono – tutti – i – bambini – che vedi
    In the paddock – there are – all – the – children – that you see
82. Il – cane – ha – tutte – le – ciotole – che vedi
    The dog – has – all – the – bowls – that you see
83. Il – cane – ha – tutti – i – formaggini – che vedi
    The – dog – has – all – the – cheeses – that you see
84. Il – pinguino – ha – tutti – i – pesci – che vedi
    The – penguin – has – all – the – fishes – that you see
85. Il – gatto – ha – tutti – i – pesci – che vedi
    The – cat – has – all – the – fishes – that you see
86. Lo – scoiattolo – ha – tutte – le – ghiande – che vedi
    The – squirrel – has – all – the – acorns – that you see
87. La – tartaruga – ha – tutte – le – lattughe – che vedi
    The – tortoise – has – all – the – lettuces – that you see
88. La – ragazza – ha – tutti – i – cani – che vedi
    The – girl – has – all – the – dogs – that you see
89. La – foca – ha – tutte – le – palle – che vedi

The – seal – has – all – the – balls – that you see

90. L'elefante – grigio – ha – tutte – le – banane – che vedi
    The gray – elephant – has – all – the – bananas – that you see
91. Il – pescatore – ha – tutti – i – pesci – che vedi
    The – fisher – has – all – the – fishes – that you see
92. Il – bambino – ha – tutte – le – matite – che vedi
    The – little boy – has – all – the – pencils – that you see
93. La – ragazza – ha – tutte – le – forbici – che vedi
    The – girl – has – all – the – scissors – that you see
94. Il – macellaio – ha – tutti – i – coltelli – che vedi
    The – butcher – has – all – the knives – that you see
95. Babbo Natale – ha – tutte – le – bambole – che vedi
    Santa Claus – has – all – the – dolls – that you see
96. La – vecchietta – ha – tutti – i – fiori – che vedi
    The – old lady – has – all – the flowers – that you see

Fillers with the quantifier "all" in false context.

97. Il – bambino – ha – tutti – i – fiori – che vedi
    The – little boy – has – all – the – flowers – that you see
98. La – bambina – ha – tutti – i – cucchiai – che vedi
    The – little girl – has – all – the – spoons – that you see
99. La – vecchietta – ha – tutte – le – caramelle – che vedi
    The – old lady – has – all – the – candies – that you see
100. Il – bambino – ha – tutte – le – bambole – che vedi
    The – little boy – has – all – the – dolls – that you see
101. Il – postino – ha – tutte – le – lattughe – che vedi
    The – postman – has – all – the – lettuces – that you see
102. Il – gatto – ha – tutti – i – formaggini – che vedi
    The – cat – has – all – the – cheeses – that you see
103. La ragazza – castana – ha – tutti – i – gatti – che vedi
    The girl – with brown hair – has – all – the – cats – that you see
104. La – strega – ha – tutti – i – gattini – che vedi

The – witch – has – all – the – kittens – that you see

105. La – nonna – ha – tutte – le – carote – che vedi

The – old lady – has – all – the carrots – that you see

106. Il – gatto grigio – ha – tutte – le – ciotole – che vedi

The – gray cat – has – all – the – bowls – that you see

107. Il – bambino – ha – tutte – le – mele – che vedi

The – little boy – has – all – the – apples – that you see

108. Il – bambino – ha – tutte – le – palle – che vedi

The – little boy – has – all – the – balls – that you see

109. La – vecchietta – ha – tutte – le – patate – che vedi

The – old lady – has – all – the – potatoes – that you see

110. L'orso – bruno – ha – tutto – il – miele – che vedi

The brown – bear – has – all – the honey – that you see

111. Babbo – Natale – ha – tutte – le – decorazioni – che vedi

Santa Claus – has – all – the – decorations – that you see

112. La – bambina – ha – raccolto – tutti – i – fiori – che vedi

The – little girl – has – harvested – all – the – flowers – that you see

113. La bambina – ha – mangiato – tutte – le – caramelle – che vedi

The little girl – has – eaten – all – the – candies – that you see

114. Nel salvadanaio – si – trovano – tutte – le – monete – che vedi

In the moneybox – there – are – all – the – coins – that you see

115. Sopra – al camino – ci sono – tutte – le – sveglie – che vedi

On – the fireplace – there are – all – the – alarm clocks – that you see

116. Sopra – alla poltrona – ci sono – tutti – i – libri – che vedi

On – the armchair – there are – all – the – books – that you see

117. Sopra – al letto – ci sono – tutte – le – bambole – che vedi

On – the bed – there are – all – the – dolls – that you see

118. Nella – buca – ci sono – tutti – gli – ossi – che vedi

In the – hole – there are – all – the – bones – that you see

119. Sul – letto – ci sono – tutte – le – stelline – che vedi

On – the bed – there are – all – the – stars – that you see

120. Nel – fiume – ci sono – tutte – le – pietre – che vedi

On – the river – there are – all – the – stones – that you see

121. L’uccello – ha – preso – tutti – i – vermi – che vedi

The bird – has – caught – all – the – worms – that you see

122. La ragazza – castana – ha – tutti – gli – uccelli – che vedi

The girl – with brawn hair – has – all – the birds – that you see

123. La – nonnina – ha – tutte – le – pagnotte – che vedi

The – old lady – has – all – the – loaves – that you see

124. Il – ragazzo – ha – tutti – i – cani – che vedi

The – boy – has – all – the – dogs – that you see

125. Il cagnolino – sta – rincorrendo – tutti – i – gattini – che vedi

The little dog – is – chasing – all – the – kittens – that you see

126. Il gatto – è seduto – sopra a – tutti – i – libri – che vedi

The cat – is sitting – on – all – the – books – that you see

127. Il gattino – sta – cacciando – tutti – gli – uccelli – che vedi

The kitten – is – chasing – all – the – birds – that you see

128. L’uccello verde – ha – preso – tutto – il – pane – che vedi

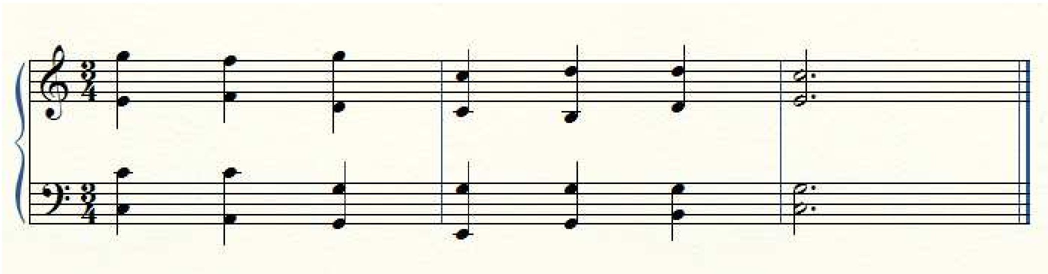
The green bird – has – caught – all – the bread – that you see

Musical stimuli

Numbers are related to the sentences above.

Musical sentences in tune

1



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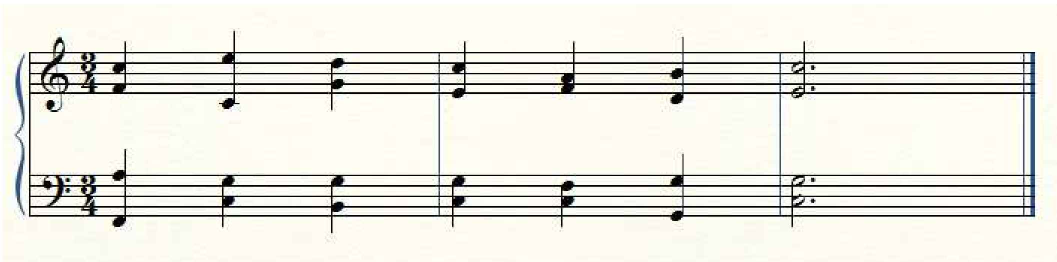

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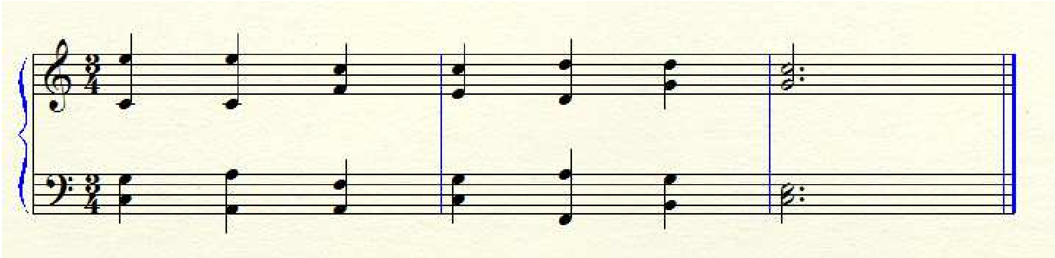

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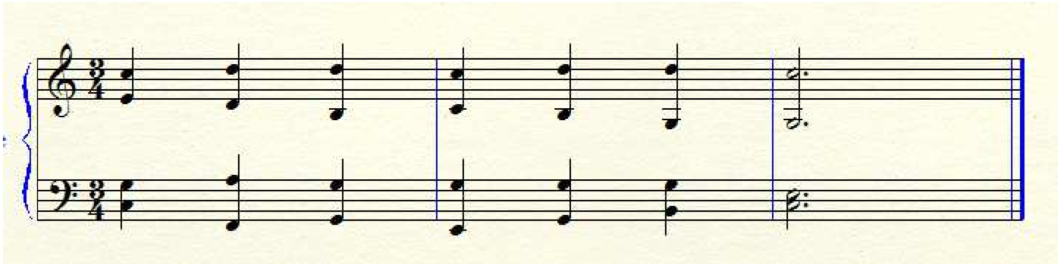

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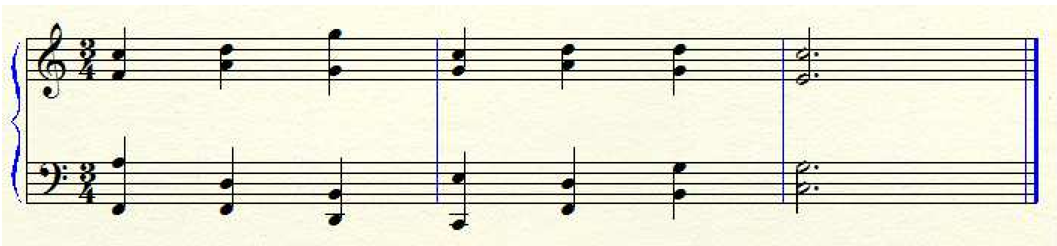

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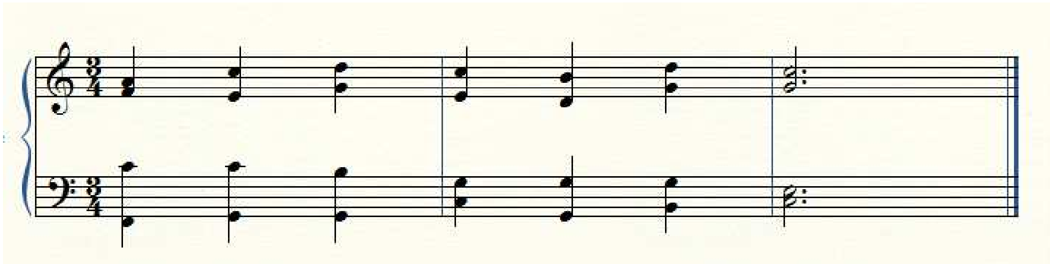

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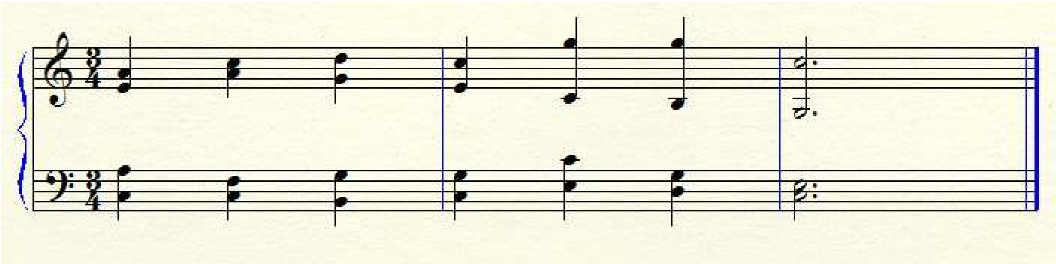

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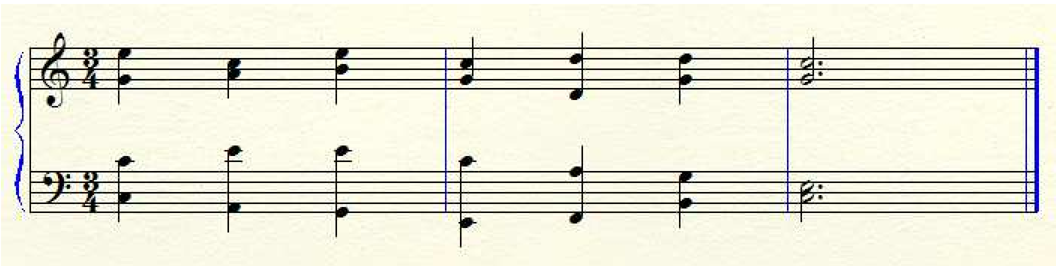

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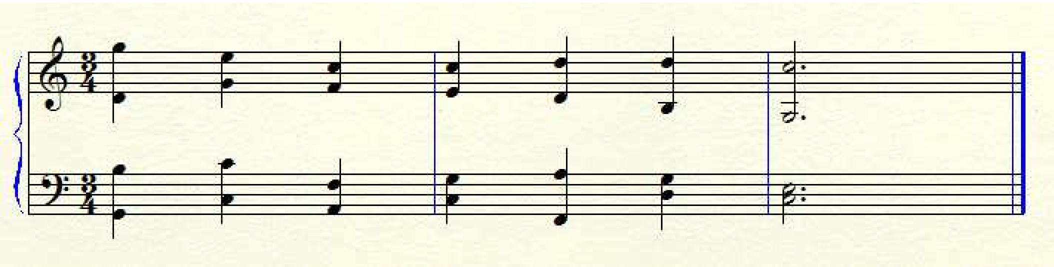

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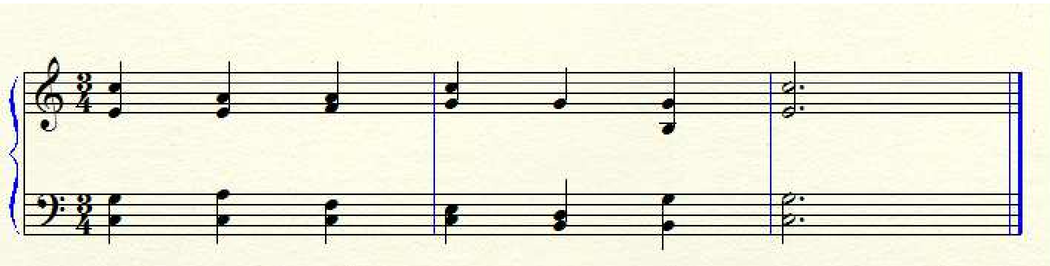

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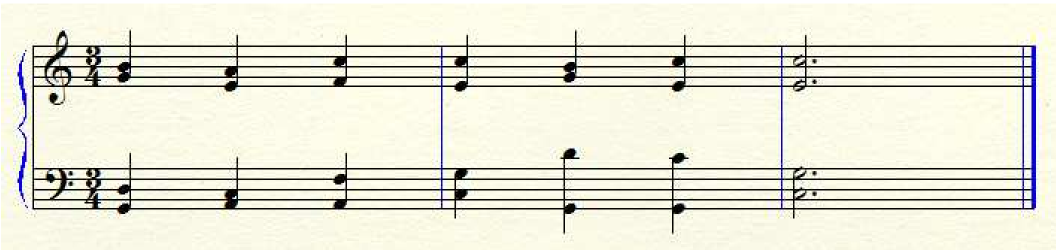

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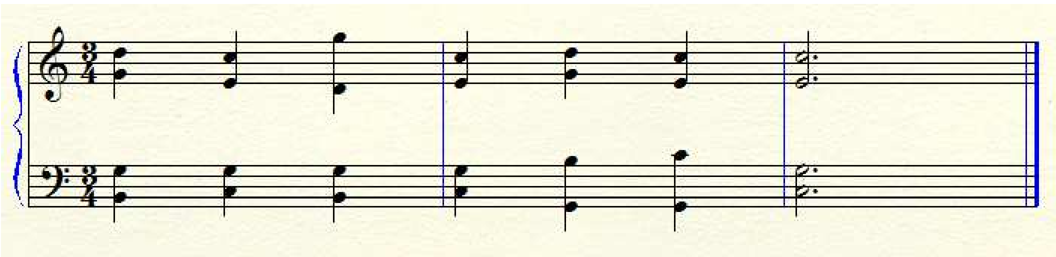

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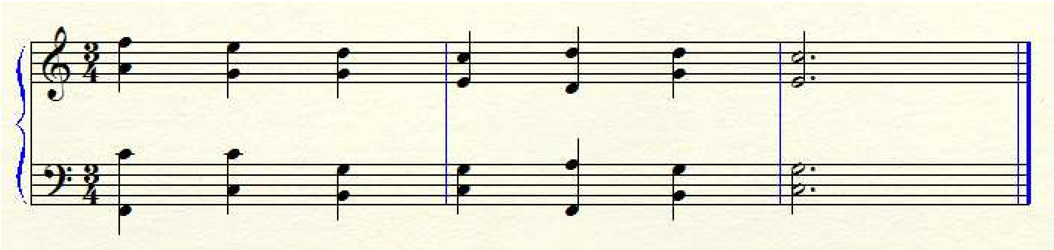

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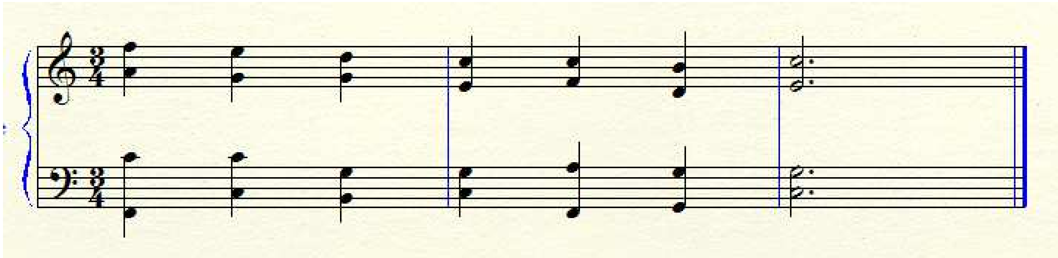

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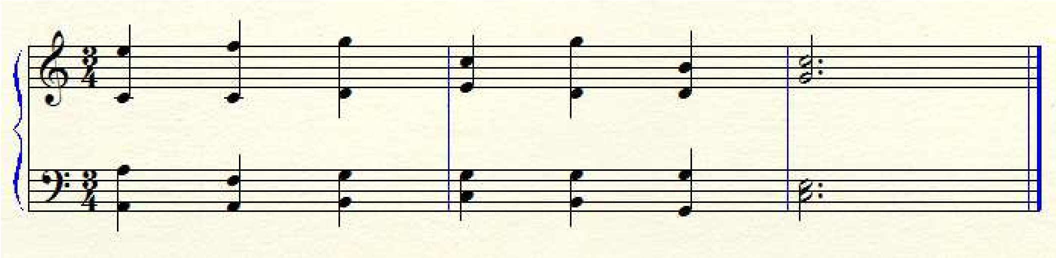

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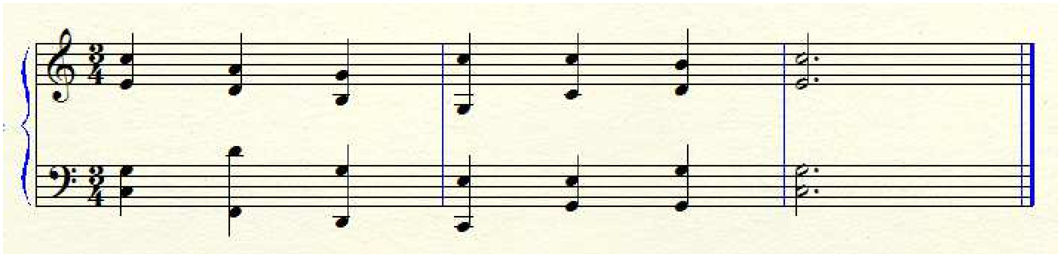

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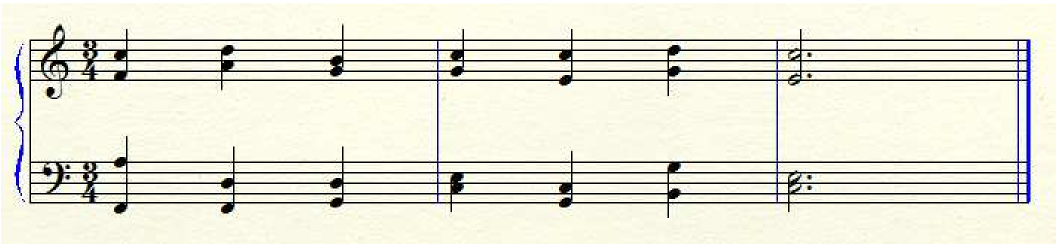

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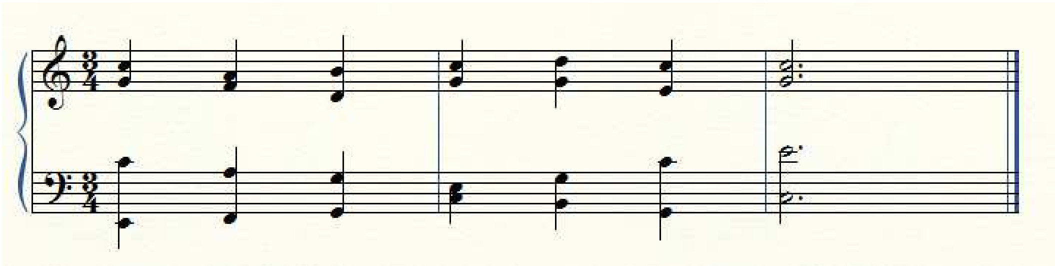


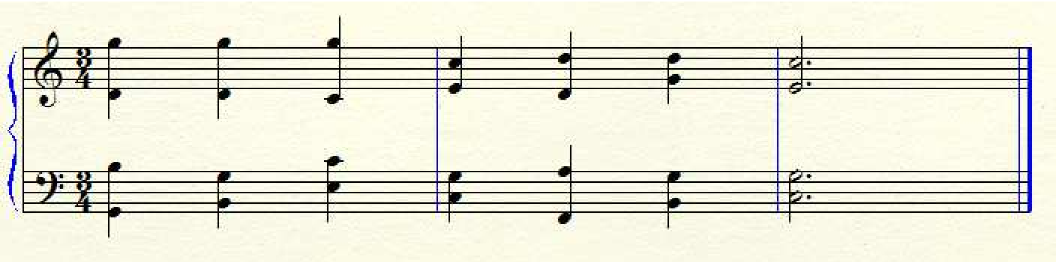
Musical sentences (in tune) with the augmented chord.

All these musical stimuli are in tune. Here, it is not stressed the augmented chord, however, it was always concomitant to the quantifier (either *some* or *all*), that is the first quarter in the second bar.

Numbers are related to the linguistic sentences above.

25

26



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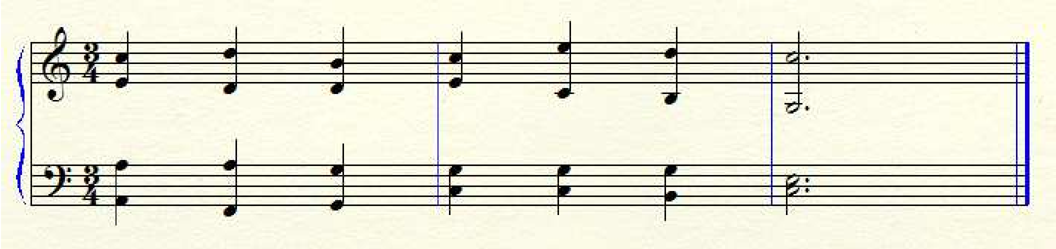

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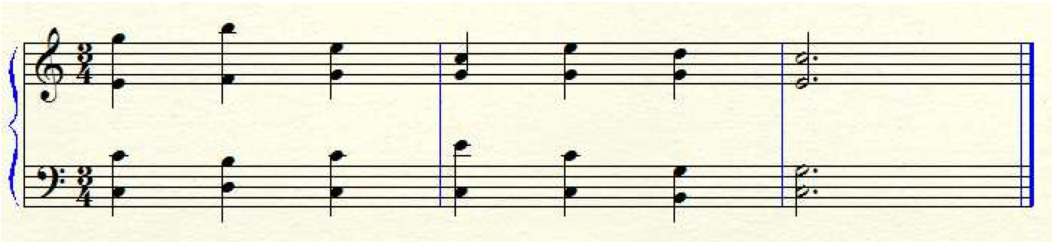

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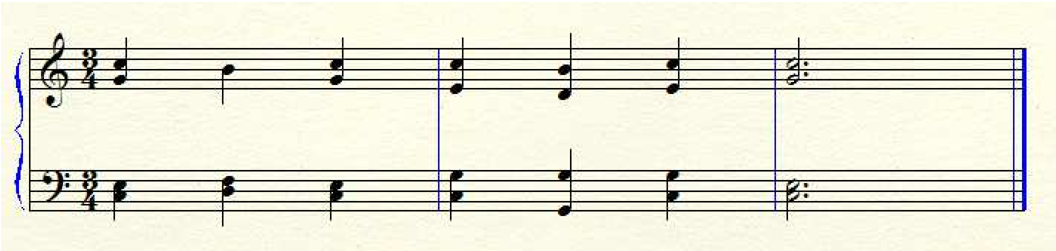

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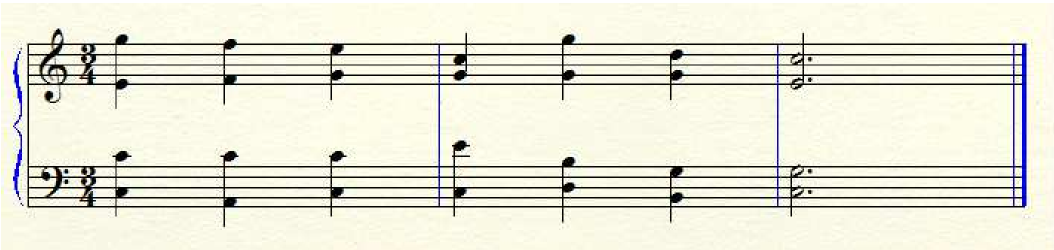

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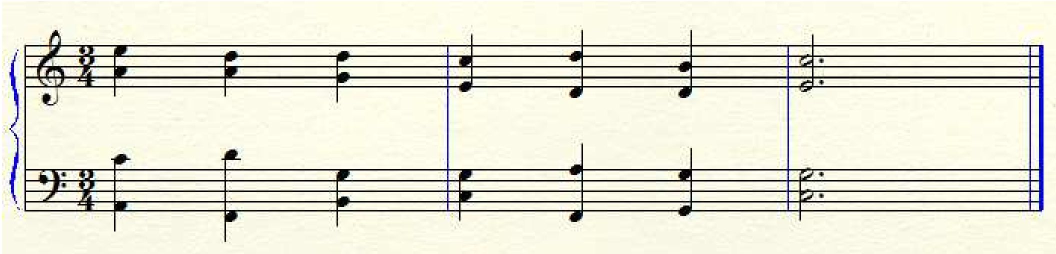

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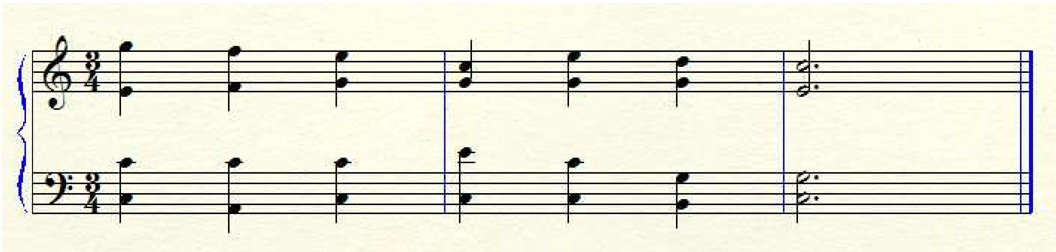

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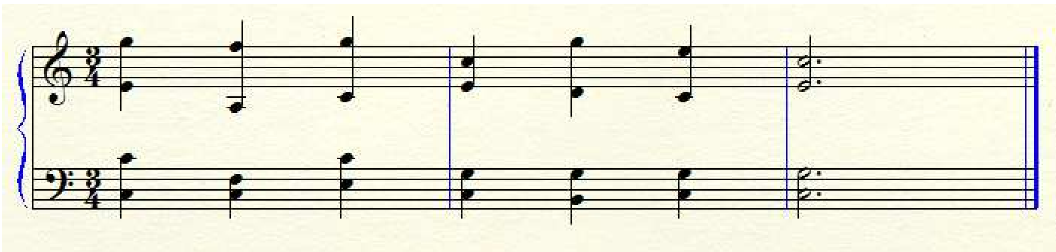

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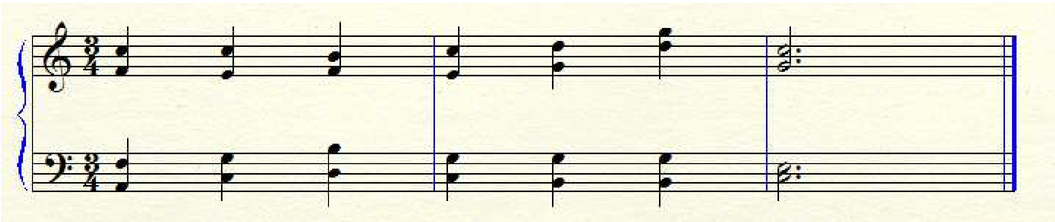

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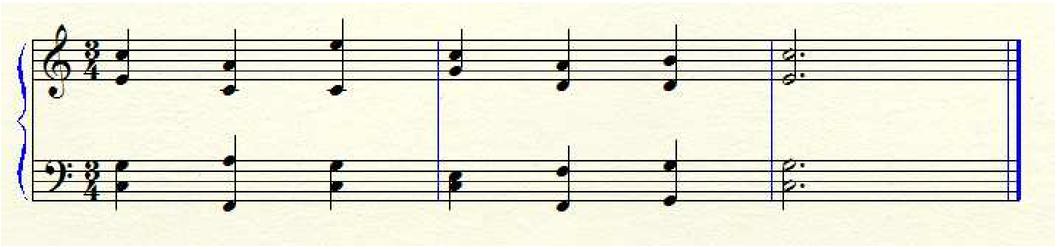

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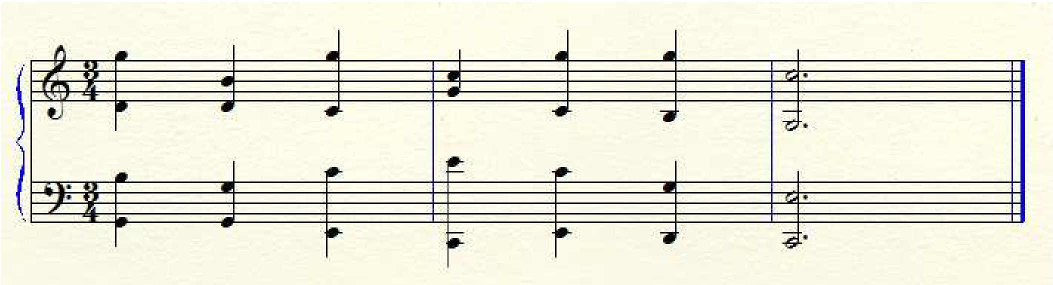

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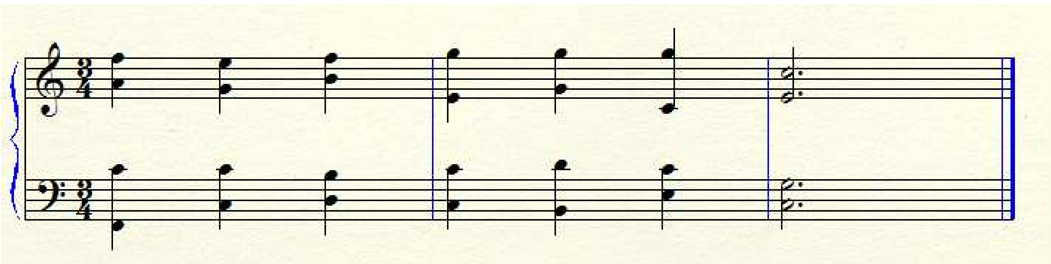

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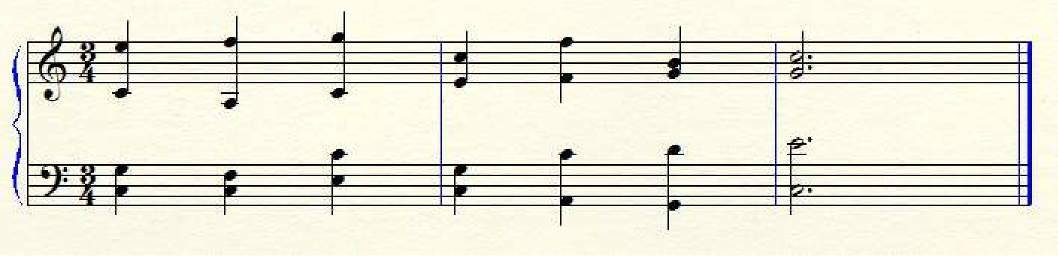

127

128

Musical sentences with dissonant target chord.

Numbers are related to the linguistic sentences above.

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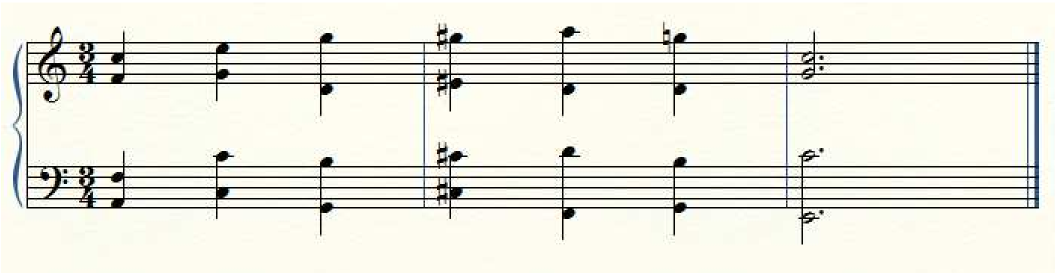

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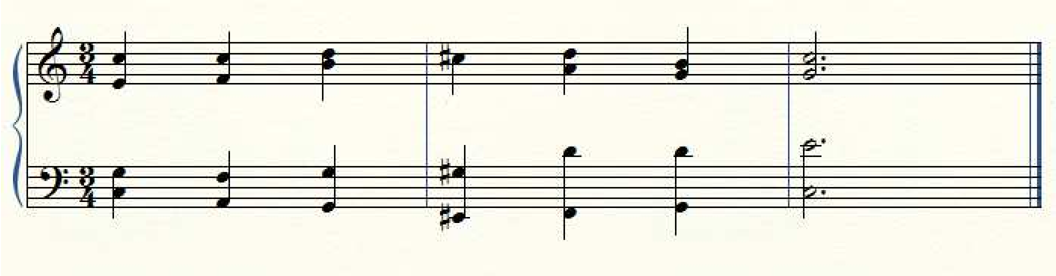

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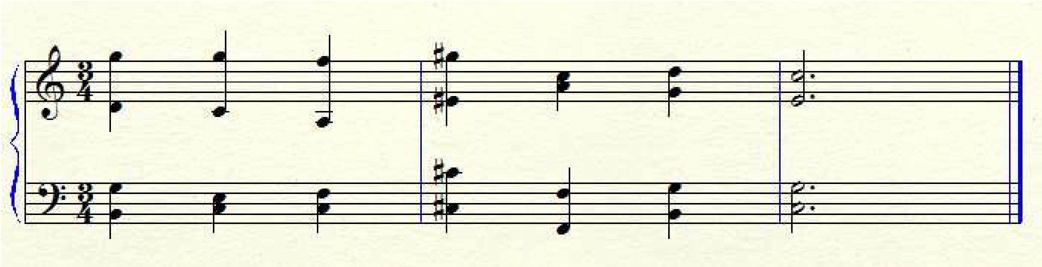

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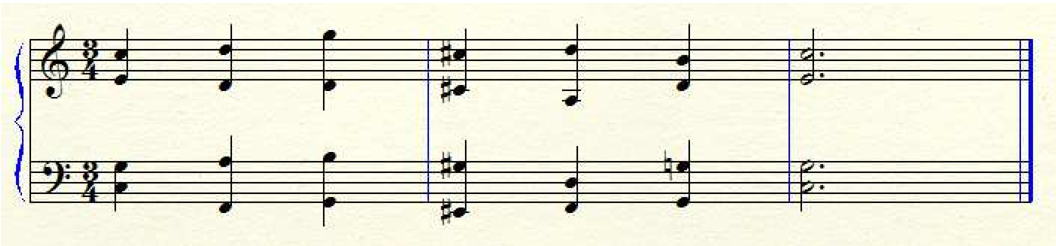

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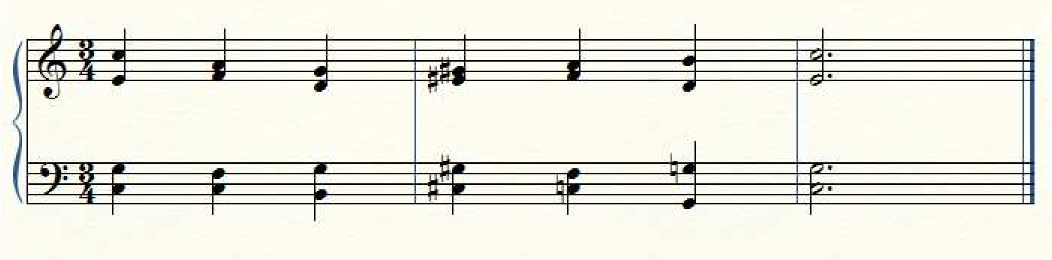

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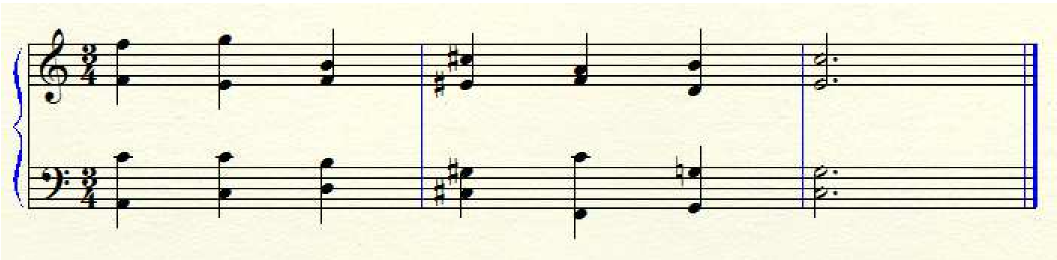

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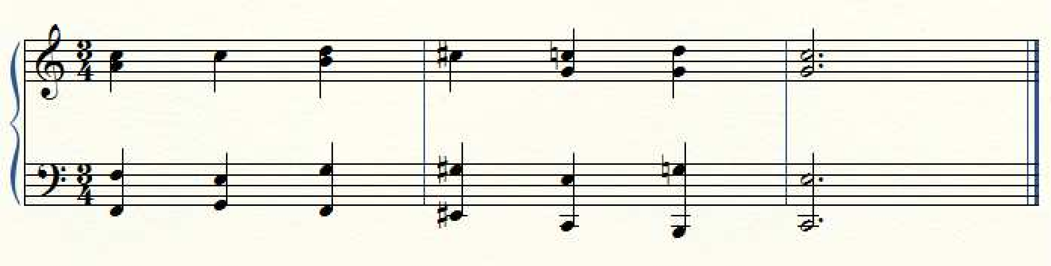

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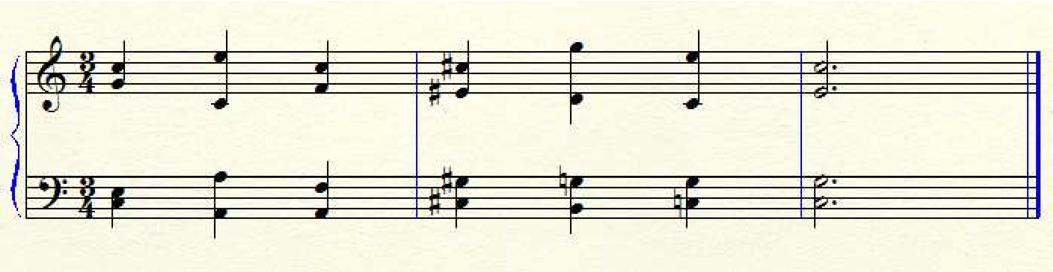

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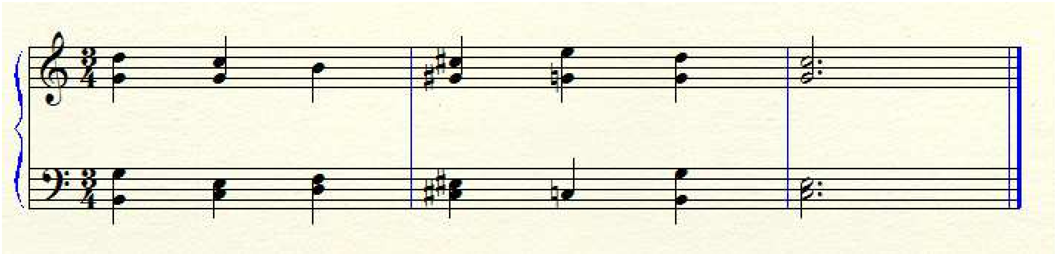

111

112

Pictures in the "Some Felicitous" conditions.

Numbers are related to the sentences above.

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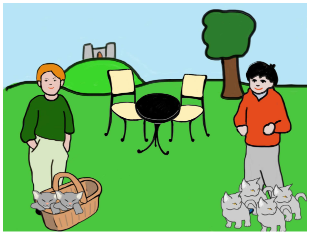

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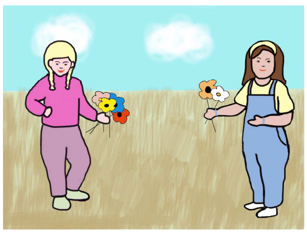

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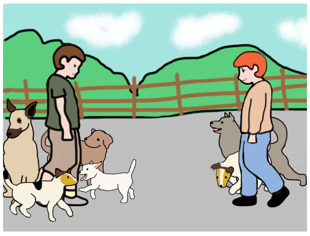

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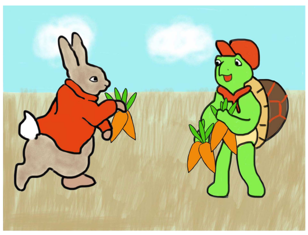

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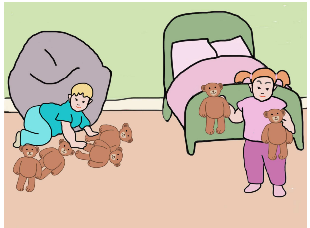

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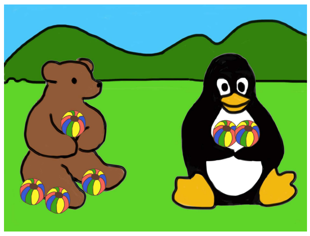

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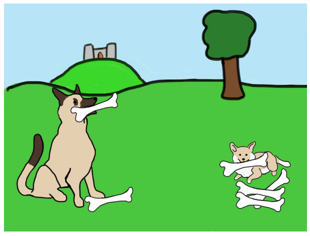

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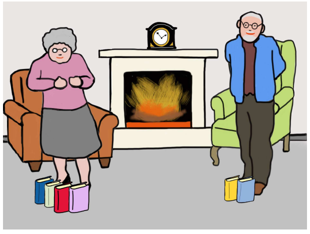
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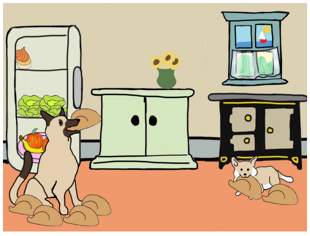
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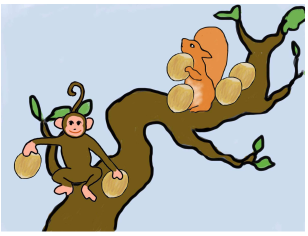
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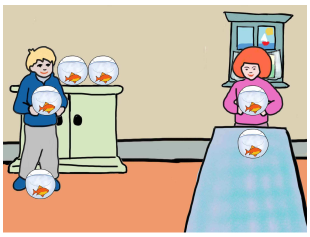
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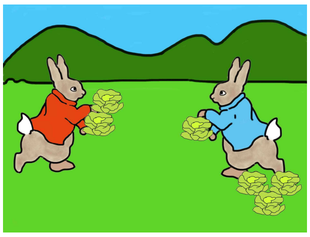
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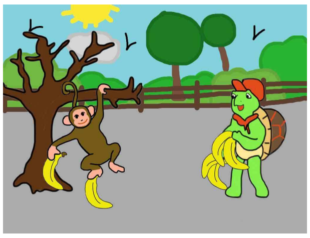
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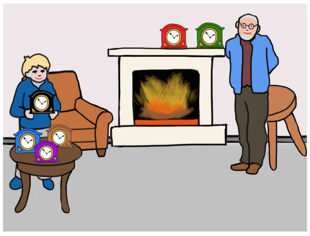
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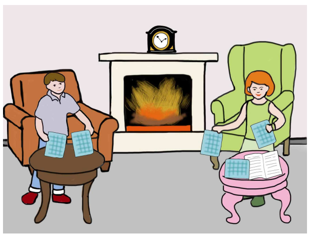
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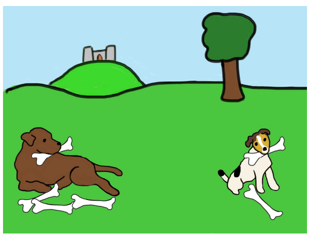
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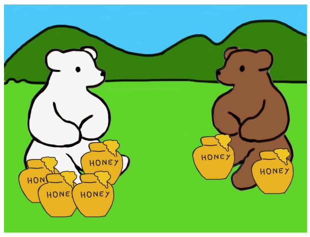

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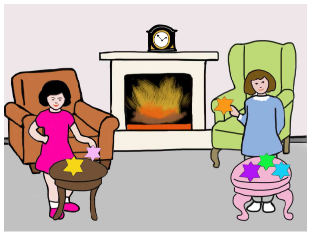
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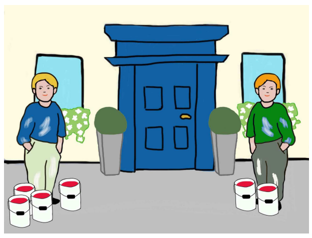
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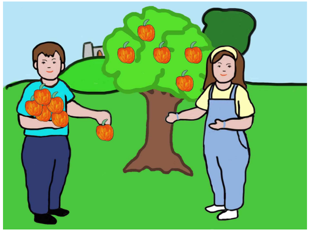
Pictures in the "Some Infelicitous" conditions.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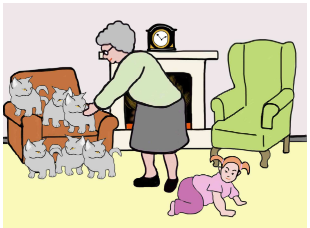
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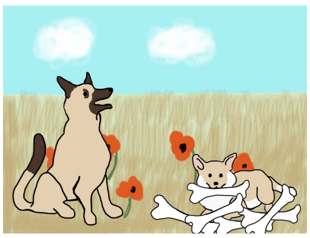
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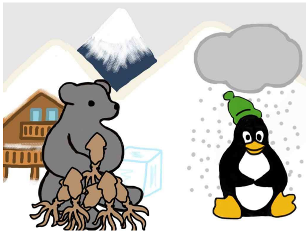
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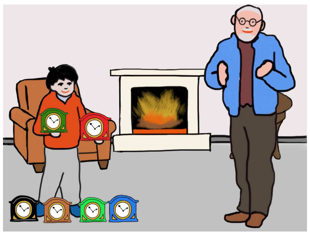
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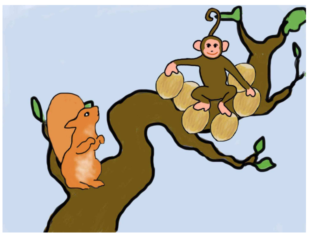
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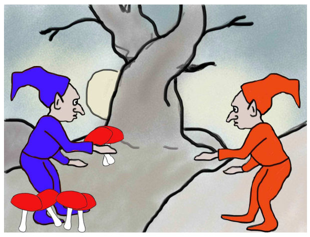
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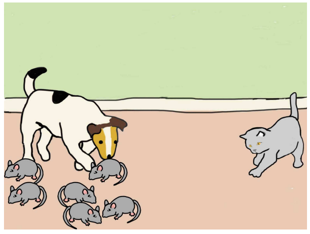
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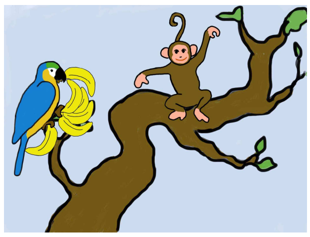
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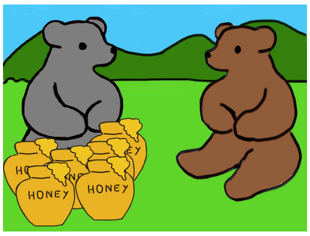

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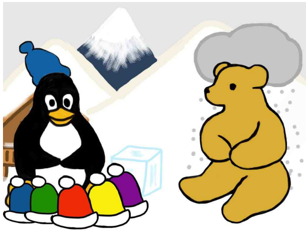
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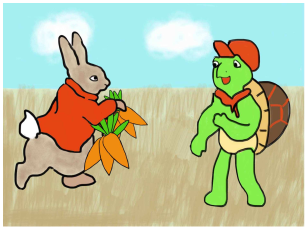
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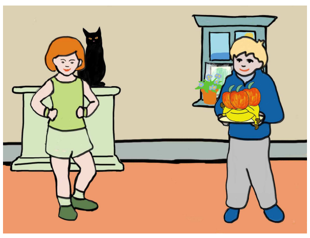
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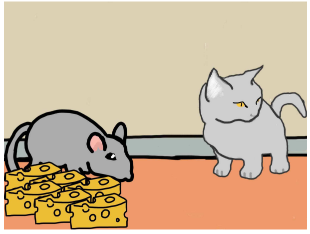
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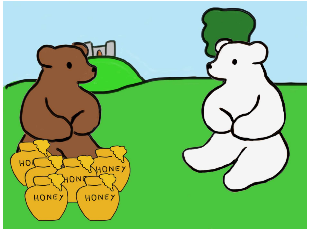

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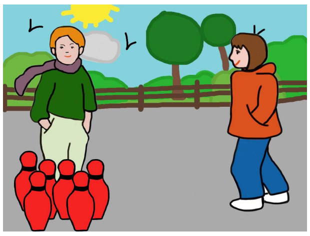
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Pictures in the fillers with "All" in True contexts


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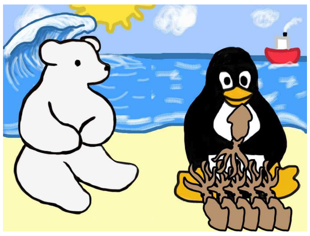
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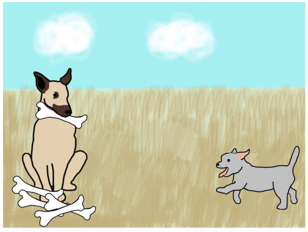
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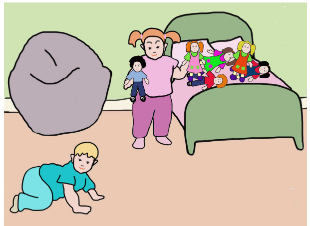
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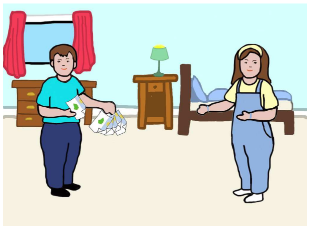
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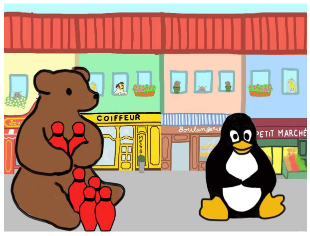

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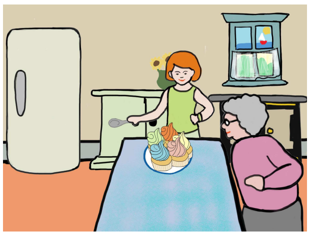
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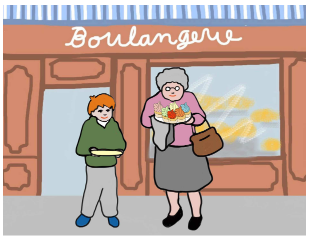

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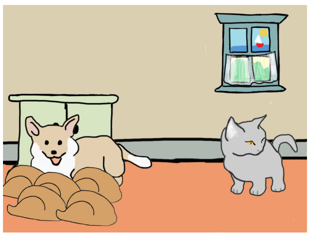
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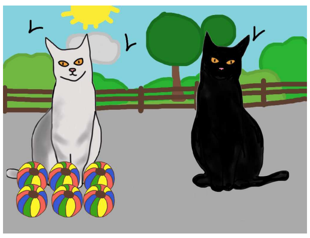
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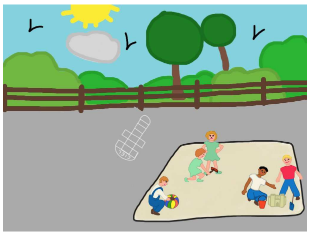
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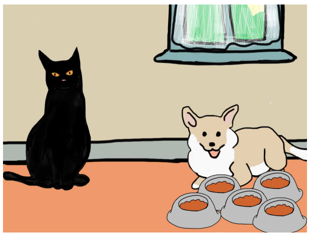
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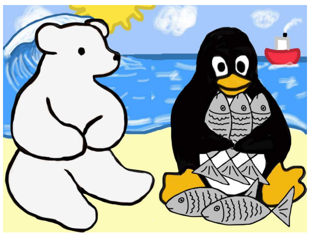
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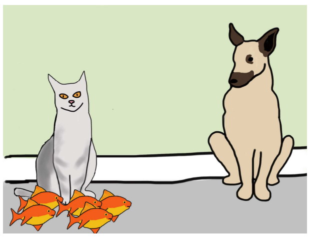
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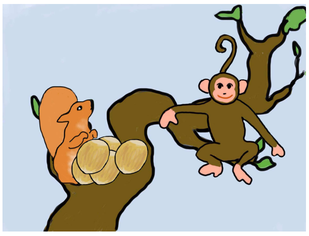
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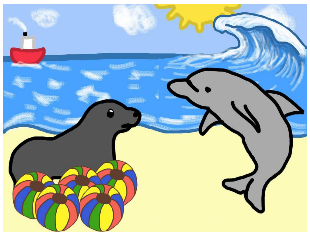
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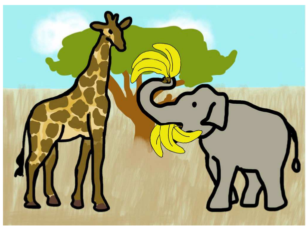
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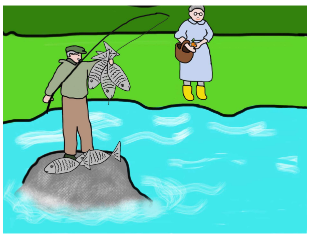
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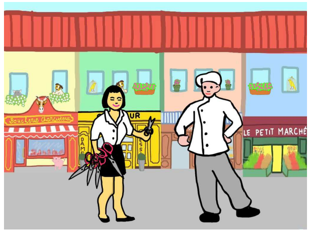

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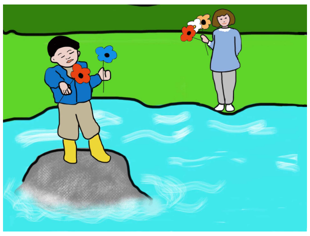
Pictures in the fillers with "All" in False contexts



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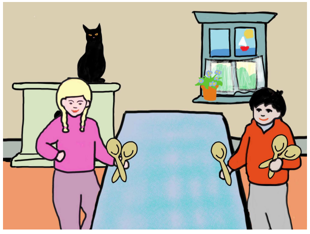

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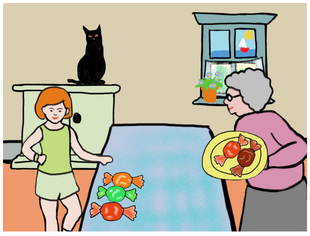

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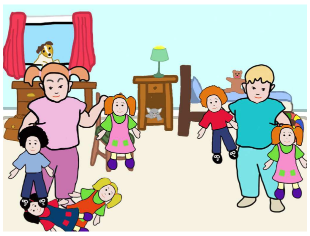

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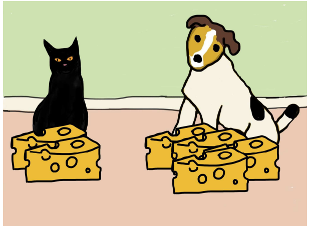

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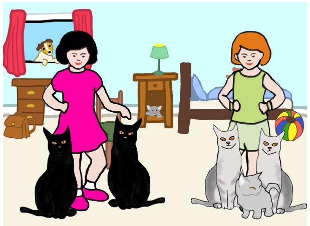

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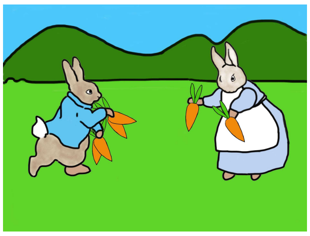

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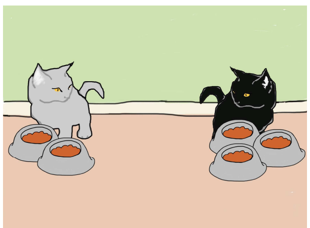

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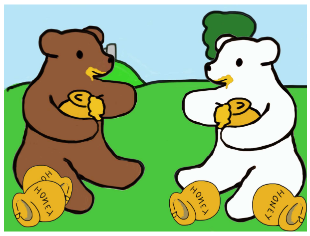

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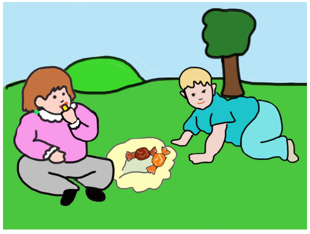

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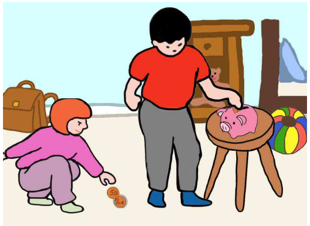

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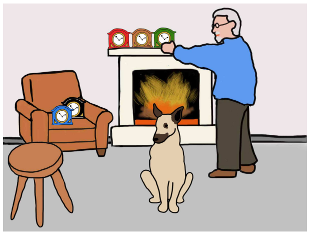

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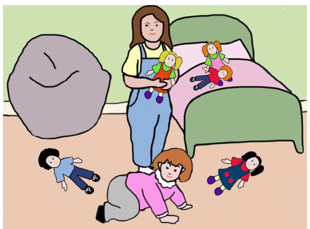

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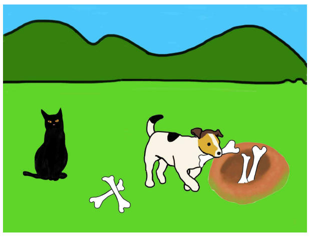

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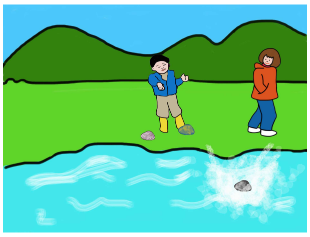

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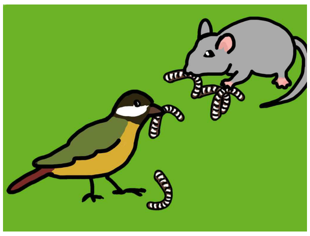

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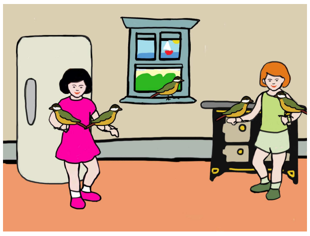

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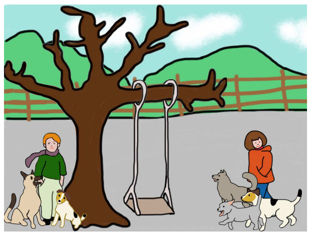

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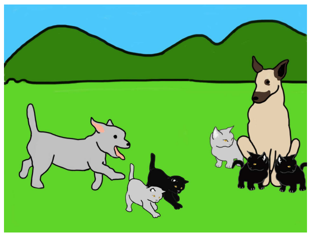

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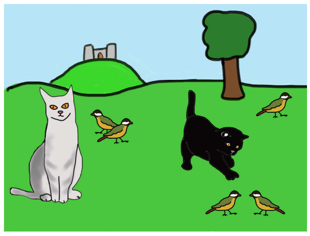

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APPENDIX C: Statistic Tables – Experiment 1

Table 1, *Descriptive plot for accuracy in Experiment 1*

	group	Mean	SD	N
ACC SFNO	M	.02	.0616	20
	NM	.036	.1002	22
	Total	.029	.0835	42
ACC SFMI	M	.0	.0	20
	NM	.009	.0426	22
	Total	.005	.0309	42
ACC SINO	M	.170	.2364	20
	NM	.327	.2931	22
	Total	.252	.2761	42
ACC SIMI	M	.310	.3275	20
	NM	.373	.2640	22
	Total	.343	.2940	42

Table 2, *mixed-design ANOVA (2×2×2) for Accuracy, Experiment 1*

	df	F	Sig.	Effect size
Language	1 40	48.098	.000	.546
Language × Group	1 40	1.465	.233	.035
Music	1 40	3.533	.067	.081
Music × Group	1 40	1.918	.174	.046
Language × Music	1 40	6.427	.015	.138
Language × Music × Group	1 40	.904	.347	.022

Table 3, *Descriptive plot for Reaction Times in Experiment 1*

	Group	Mean	SD	N
RT SFNO	M	1527.09	638.07	16
	NM	1532.20	473.70	19
	Totale	1529.86	546.28	35
RT SFMI	M	1507.63	582.99	16
	NM	1662.07	621.23	19
	Totale	1591.47	600.29	35
RT SINO	M	1447.60	466.18	16
	NM	1788.02	574.41	19
	Totale	1632.40	547.87	35
RT SIMI	M	1553.96	688.81	16
	NM	1864.18	839.80	19
	Totale	1722.36	779.29	35

Table 4, *mixed-design ANOVA (2×2×2) for Reaction Time, Experiment 1*

	df	F	Sig.	Effect size
Language	1 33	3.302	.078	.091
Language × Group	1 33	4.415	.043	.118
Music	1 33	1.147	.292	.034
Music × Group	1 33	.190	.666	.006
Language × Music	1 33	.085	.772	.003
Language × Music × Group	1 33	.528	.473	.016

Table 5, *Descriptive plot of the t-test between SF Vs. SI, Musicians*

		Mean	N	SD
Pair 1	RT SF	1558,038750	20	599,0953147
	RT SI	1668,795830	20	739,8207757

Table 6, *Paired-samples t-test for Musicians, RT in Experiment 1*

		Mean	SD	t	df	Sig.
Pair 1	RT FEL – RT INF	-110.7570800	392.4067880	-1.262	19	.222

Table 7, *Descriptive plot of the t-test between SF Vs. SI, Non-musicians*

		Mean	N	SD
Pair 1	RT FEL	1525,676518	22	516,0397985
	RT INF	1733,720073	22	641,7589728

Table 8, *Paired-samples t-test for Non-musicians, RT in Experiment 1*

		Mean	SD	t	df	Sig.
Pair 1	RT FEL - RT INF	-208.0435545	389.3266592	-2.506	21	.020

APPENDIX D: Statistic Tables – Experiment 2

Table 9, *Descriptive plot of the t-test MI vs MS divided per groups. M= group1; NM= group 2, Preliminary test*

Group			Mean	N	SD
1	Pair 1	MI	5.33125	15	0.7762159
		MS	3.6375	15	1.2596059
2	Pair 2	MI	4.779297	16	0.7132004
		MS	2.972656	16	0.7679175

Table 10, *Paired-sample t-test MI vs. MS for group 1 (musicians) and group 2 (non-musicians), Preliminary test*

Group		Mean	SD	t	df	Sig.
1	MI - MS	1.6937500	.8515840	7.703	14	.000
2	MI - MS	1.8066406	1.0519834	6.869	15	.000

Table 11, *Descriptive plot for Accuracy, Experiment 2*

	Group	Mean	SD	N
ACC SFNO	Mus	.04	.059	20
	Nonmus	.04	.060	22
	Tot	.04	.058	42
ACC SFMI	Mus	.03	.069	20
	Nonmus	.03	.066	22
	Tot	.03	.067	42
ACC SFMS	Mus	.04	.084	20
	Nonmus	.03	.054	22
	Tot	.04	.069	42
ACC SFA	Mus	.06	.086	20
	Nonmus	.05	.100	22
	Tot	.05	.092	42
ACC SINO	Mus	.02	.061	20
	Nonmus	.16	.350	22
	Tot	.10	.265	42
ACC SIMI	Mus	.11	.084	20
	Nonmus	.28	.314	22
	Tot	.20	.249	42
ACC SIMS	Mus	.08750	.115423	20
	Nonmus	.18750	.329027	22

	Tot	.13988	.253335	42
ACC SIA	Mus	.03	.065	20
	Nonmus	.18	.327	22
	Tot	.11	.251	42

Table 12, *mixed-design ANOVA (2×2×4) for accuracy, Experiment 2*

	df	F	Sig.	Effect size
Language	1 40	6.183	.017	.134
Language × Group	1 40	4.097	.050	.093
Music	2 97	5.630	.003	.123
Music × Group	2 97	1.328	.271	.032
Language × Music	3 120	9.654	.000	.194
Language × Music × Group	3 120	.640	.591	.016

Table 13, *Descriptive plot for Reaction Time, Experiment 2*

	Group	Mean	SD	N
RT SFNO	M	1471.911	513.794	20
	NM	1396.515	501.376	18
	Totale	1436.197	502.507	38
RT SFMI	M	1385.671	450.433	20
	NM	1353.239	488.692	18
	Totale	1370.308	462.800	38
RT SFMS	M	1394.950	494.521	20
	NM	1290.400	538.470	18
	Totale	1345.426	511.468	38
RT SFA	M	1426.168	502.620	20
	NM	1342.646	486.458	18
	Totale	1386.605	490.143	38
RT SINO	M	1463.443	506.263	20
	NM	1308.035	459.386	18
	Totale	1389.829	484.521	38

RT SIMI	M	1455.867	472.955	20
	NM	1318.079	558.437	18
	Totale	1390.599	512.845	38
RT SIMS	M	1470.805	473.808	20
	NM	1271.768	468.656	18
	Totale	1376.524	475.751	38
RT SIA	M	1440.259	458.407	20
	NM	1473.267	584.373	18
	Totale	1455.894	514.868	38

Table 14, *mixed-design ANOVA for Reaction Time data, Experiment 2*

	df	F	Sig.	Effect size
Language	1	.387	.538	.011
	36			
Language × Group	1	.527	.473	.014
	36			
Music	3	1.076	.362	.029
	108			
Music × Group	3	.906	.441	.025
	108			
Language × Music	3	1.058	.370	.029
	108			
Language × Music × Group	3	1.178	.322	.032
	108			

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